

## AN ABSTRACT OF THE THESIS OF

Christina N. Welch for the degree of Master of Science in Water Resources Policy and Management  
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Title: What Lies Below: Options to Improve Sustainable Management of U.S./Mexico Transboundary  
Aquifers

Abstract approved:

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Aaron T. Wolf

Globally, as surface water quality and quantity diminishes there is increasing reliance on groundwater to buffer water demands of growing populations. Today in many arid regions around the world aquifer pumping rates far exceed recharge rates. Often the groundwater is nonrenewable, or thousands of years old. Despite the known hydrologic connection between surface and groundwater, existing institutions and laws governing surface water are poorly equipped to manage groundwater. While there are more than 600 international treaties governing surface water, only one treaty worldwide explicitly addresses groundwater allocation. Like many other regions of the world, the treaties covering the Paseo del Norte region shared between Mexico and the United States allocate the quantity and timing of surface water deliveries, yet fail to regulate groundwater abstraction. The three transboundary aquifers shared by two countries and three states (New Mexico/U.S., Texas/U.S., and Chihuahua/MX) within Paseo del Norte study area present an ideal microcosm to closer examine water management institutions across the local, state, national, and international scales. This research assesses the United States and Mexico's institutional capacity to manage groundwater across each scale. The problem is imminent since the Hueco Bolson transboundary aquifer is the primary source of drinking water for nearly 2 million people and the fresh water is predicted to be completely depleted between 2020-2050. The ultimate objective is to identify which future legal, scientific and economic options can best contribute to more sustainable management of transboundary aquifers without compromising water security in both countries. This research proposes three major paths to move forward: the first step is to increase public awareness of the aquifer exploitation problem; second, for water managers to accurately plan for future water demands there should be a binational groundwater model built by scientists on both sides of the border; third, an international treaty or regional joint agreement is necessary to legally support groundwater management efforts.

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What Lies Below: Options to Improve Sustainable Management of U.S./Mexico Transboundary Aquifers

by

Christina N. Welch

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Christina N. Welch, Author

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## TABLE OF CONTENTS

	<u>Page</u>
CHAPTER I. INTRODUCTION .....	1
1.1 Justification of Research .....	1
1.2 Research Questions .....	4
1.3 Study Area .....	5
1.2.1 Aquifers .....	8
1.4 Background: .....	15
1.4.1 Groundwater users .....	15
1.4.2 Groundwater Uses .....	17
1.5 Groundwater Governance .....	21
1.5.1 Theory and Practice .....	21
1.5.2 United Nations .....	27
1.5.3 Principles of International Water Law .....	31
1.5.4 Existing Groundwater Agreements Worldwide .....	35
1.6 Methodology Justification .....	37
 CHAPTER II. METHODS .....	 40
2.1 Global Analysis .....	40
2.1.1 GIS ArcMap Methods .....	41
2.2 Case Study .....	42
2.2.1 Interviews .....	42
2.2.2 Assessment of Institutional Potential for Cooperation .....	44
 CHAPTER III. RESULTS .....	 47
3.1 Spatial Analysis, <i>Global Scale</i> .....	47
3.2 Case Study, <i>International, State, Regional Analysis</i> .....	49
3.2.1 Legal Mechanisms .....	49
3.2.2 Governmental Institutions .....	64
3.2.3 Third party Involvement .....	72
3.2.4 Previous Water Cooperation .....	74
3.2.5 Scientific Research .....	78
3.2.6 Funding mechanisms .....	80
3.2.7. Political will .....	82
3.3 Results from Interviews .....	91
 CHAPTER IV. DISCUSSION .....	 95
4.1 Analysis of Results .....	95
4.2 Proposed Options for Future Management .....	97
4.3 Discussion of Options .....	104
4.4 Limitations .....	107

CHAPTER V. CONCLUSION and RECOMMENDATIONS .....	109
5.1 Recommendations .....	109
5.2 Implications for the Paseo del Norte Region .....	111
 Bibliography .....	115
APPENDIX A. List of Acronyms.....	129
APPENDIX B. Definitions .....	130
APPENDIX C. IRB Exemption Form .....	132
APPENDIX D. List of Interviewees .....	133

## LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
Figure 1. Paseo del Norte region highlighted in dark orange .....	8
Figure 2. Three principal aquifers in the Paseo del Norte region .....	9
Figure 3. Geologic cross section of the Mesilla and Hueco bolsons .....	11
Figure 4. Hueco bolson pumping from 1903-1996.....	14
Figure 5. Municipal wells Ciudad Juarez and El Paso.....	17
Figure 6. Applicable Groundwater Principles .....	33
Figure 7. Categories of Interviewees, number represents number of people interviewed.....	43
Figure 8. Global Transboundary River Basins with a Treaty .....	46
Figure 9. Global Transboundary River Basin with Treaty Overlap with Transboundary Aquifer.....	47
Figure 10. Rio Grande/Bravo Basin Study Area with applied Transboundary Aquifer Map.....	48
Figure 11. Location of Diversion Dams and Canals on the Upper Rio Grande/Bravo River.....	53
Figure 12. Relevant United States Government Organizational Structure .....	67
Figure 13. Depicts the concrete channel constructed between El Paso and Ciudad Juarez.....	85
Figure 14: Rio Grande/Bravo River, January 2017.....	92
Figure 15. Example groundwater monitoring well with groundwater levels publically accessible. ....	103

## LIST OF TABLES

<u>Table</u>	<u>Page</u>
Table 1. Names for the same resource used interchangeably throughout the text.....	6
Table 2. Compilation of Known Aquifer Characteristics .....	14
Table 3. Current Water Demand El Paso and Ciudad Juarez. ....	16
Table 4. Timeline of International Instruments with Transboundary Groundwater Implications .....	29
Table 5. Explanation of Principles .....	33
Table 6. Groundwater Sharing Arrangements.. ....	36
Table 7. Sources of primary GIS data used in the analysis .....	40
Table 8. Timeline of Treaties in Rio Grande Basin .....	50
Table 9. Timeline of New Mexico Ground Water Policy .....	55
Table 10. Treaty Obligations .....	66
Table 11. Compiled Ranking .....	90
Table 12. Cooperation Legend.....	90
Table 13. Final Institutional Capacity Index Results .....	90



## CHAPTER I. INTRODUCTION

### 1.1 Justification of Research

“Water can enlarge perception. It is an active agent, changing all it touches.”

(Blatter, Ingram and Doughman, 2001 p.1)

Groundwater accounts for 98-99% of the available freshwater resources globally (Margat and Van der Gunn, 2013) and it is the main source of drinking water for more than half of the world's population (Zekster and Everett, 2004). Consequently, groundwater is designated as the most extracted natural resource on Earth (Eckstein, 2007). Scientists predict future extreme drought is expected to alter the hydrologic cycle by decreasing the availability of surface water, precipitation and soil moisture in arid regions (Gleeson et al., 2012; Taylor et al., 2013). Today, the visible decrease in surface water availability in dry regions applies stress on groundwater resources to meet current demands. Though global freshwater demand has increased, the amount of water available to the world today is nearly the same as it was at the beginning of human civilization (Postel and Wolf, 2001).

The dynamic equilibrium of the hydrologic cycle often promotes the misconception groundwater is renewable (Thomas and Leopold, 1964). Contrarily, Theis 1940 argues every time a pump is turned on, groundwater is mined. This research adopts the Gleick and Palaniappan 2010 assertion that groundwater is neither completely renewable or nonrenewable. The level of renewability is largely dependent on a sliding timescale ranging from a few months to millions of years, the scale of the groundwater system, and hydrologic connectivity (Gleeson et al., 2016). The majority of global groundwater used today was recharged during the cold, wet conditions of the Late Pleistocene and Early Holocene ( $\geq 5,000$  BP) (Taylor, et al., 2013). Respectively, less than 6% of groundwater is “*modern* or less than 50 years old” (Gleeson et al., 2016 p. 1). Therefore the majority of groundwater should be conceptualized as nonrenewable. Similar to fossil fuels, “*fossil*” groundwater is groundwater that is defined as old water measured by millennia (Margat et al., 2006). Once extracted, it will not recharge within a usable human lifespan (Thomas and Leopold, 1964). Although each groundwater system is highly unique, aquifers may contain one type or both modern and fossil water.

Groundwater stress, or exploitation occurs in the systems “where withdrawals exceed capture such that storage loss occurs” (Richey et al., 2015). Land subsidence is one of the most visible effects of

groundwater exploitation. Once the water is removed the soil compacts to fill the empty pore space, permanently damaging the soil structure and rendering future recharge impossible. Major cities around the world ranging from Jakarta, Indonesia; Mexico City, Mexico; San Jose, California; Kolkata City, India; Shanghai, China are seeing serious land subsidence due to overpumping of groundwater (Holzer and Johnson, 1985; Sahu and Sikdar, 2011). According to Utton and Hayton 1989, acknowledging humans are causing irreversible damage to groundwater resources is an important first step to managing groundwater more sustainably.

Over the past century, Llamas and Martinez-Santos 2005 propose there is a “silent revolution” comprised of millions of irrigation farmers around the world that have increasingly become dependent on intensive pumping of groundwater resources. Although this has resulted in economic benefit for the countries as a whole, it is paralleled by a serious lack of regulation by governmental agencies to control pumping rates. Today most governments do not have a comprehensive accurate record of who is pumping how much, when, and where (E. Eckstein and Y. Eckstein, 2005).

One of the reasons for the lack of attention stem from the historical perception of groundwater as a hidden, mysterious resource (L. Teclaff and E. Teclaff, 1981). Current modeling technology has evolved to sufficiently debunk the mysterious nature, yet the complexity still remains. The factors that affect groundwater movement are not limited to: the hydraulic conductivity, gradient, pressure, water chemistry, water table levels, soil permeability, connectivity to recharge zones, storage capacity, aquitards (Sheng and Devere, 2005). To accurately measure groundwater movement, it is imperative to first understand the geologic properties. Bridging the gap between scientists and policy makers requires adequate scientific knowledge of the groundwater boundaries, hydraulic head, gradient, potential sources of contamination, areas of recharge and discharge. Fifty years is the recommended threshold in which to plan for groundwater use (Llamas and Martínez-Santos, 2005; Llamas and Custodio, 2002; Gleeson et al., 2016). For water managers to effectively plan to meet water demand with supply, answering basic questions such as [How much groundwater is available? What is the depth of water table? Is it drinking quality? When will the aquifer be exhausted?] often take extensive scientific modeling and research. This level of complexity partially explains why knowledge of groundwater is largely unknown in many parts of the world.

There is not a universally agreed upon conceptual model for how society perceives, values, and communicates over groundwater (Jarvis, 2011). Across the local, state and national scales groundwater exploitation worldwide is being “either ignored, cursorily misunderstood or intentionally disregarded” from political, public and legal discourse (Eckstein and Sindico, 2014 p.33). Milman and Ray 2011 suggest the reason “transboundary aquifers are particularly difficult to characterize is because information must cover the extent of the aquifer across multiple countries and data on piezometric levels, and flows taken from each side of the border should cover a similar timeframe and sampling frequency” (p. 632).

At the international scale, groundwater legal normative framework is still in the infancy stage (Conti and Gupta, 2016; Utton, 1981). On a global scale the Oregon State Transboundary Freshwater Dispute Database has mapped over 309 transboundary river basins worldwide (McCracken, 2017) and governed by more than 400 international surface water treaties of which 15% mention groundwater (Jarvis, 2006). The International Groundwater Resources Assessment Center (IGRAC) has mapped over 600 transboundary aquifers (IGRAC, 2014; Sanchez et al., 2016).

Through an extensive literature review I determined eight transboundary aquifers have documented informal agreements, six of which have legal mechanisms attached (Conti and Gupta, 2016). From the eight aquifers the only one with a treaty which explicitly addresses groundwater allocation is the Genevese aquifer (Wohlwend, 2002). In 2015 the Al-Sag/Al-Disi aquifer agreement became the second most specific agreement, effectively establishing protection and management zones (Eckstein, 2015). Two agreements for the Nubian Sandstone and Northwestern Sahara aquifers establish groundwater data sharing arrangements (Sanchez et al., 2016). The remaining four agreements are informal handshake arrangements. Relevant to this research, one of these agreements is a memorandum of understanding regarding groundwater signed between Ciudad Juarez, MX and El Paso, USA (IBWC, 2012; MOU, 1999). There is not currently a nationally recognized agreement on groundwater between the United States and Mexico.

The primary problem this research addresses is aquifer overexploitation, a concept cited by the Earth Security Group 2016 as a “systemic risk to one billion people in the world’s growing economies.” The complexity of the problem is compounded when geopolitical borders with disparate regulations, laws, and cultural views overlay the natural groundwater basin. The Rio Grande River Basin offers an ideal microcosm in which to explore the dynamics of transboundary groundwater management across scales.

Declining groundwater levels, deteriorating water quality and rapidly increasing population in the Paseo del Norte region of the Rio Grande Basin is representative of the issues faced along the entire United States and Mexico border (Carter et al., 2015; Eckstein, 2011). Along the border there are an estimated 8-38 potential transboundary aquifers, although there is not an official number either of the governments recognize (Sanchez et al., 2016). Groundwater which was at one time only used only as a supplement to surface water during drought, has now become the primary source of drinking water for nearly 2 million people living in the Paseo del Norte region (Schmandt, 2002). Both governments broadly recognize conserving groundwater is essential to the broader economic, ecological and security interests at large (Schaefer, 2009). However current research predicts the complete depletion of “economically recoverable freshwater supplies” in the Hueco Bolson aquifer between the years 2020 and 2050 (Hume, 2000; Evans, 2006; U.S. ACE, 2009; Sheng, Mace and Fahy, 2001). This research addresses the problem of transboundary aquifer exploitation by identifying institutional options to increase the longevity of the groundwater.

## **1.2 Research Questions**

There are three main questions guiding this research. The two specific sub-questions provide the boundaries for the scope of the assessment and were designed to complement the primary, broad question.

### Primary:

1. What are options to sustainably manage transboundary groundwater?

### Sub-questions:

2. Institutions are currently best equipped to jointly manage groundwater across which scales?
3. How can legal, economic and scientific options contribute to more sustainable management of transboundary groundwater across scales [local, state, national, and international]?

The goal of this research is to ultimately propose institutional based options to enhance the sustainability of the groundwater. I postulated one of the most feasible possibilities would be to amend the current surface water treaty to include groundwater. The case study in the Paseo del Norte region was selected to assess the current existing institutional capacity to manage groundwater at all scales. Learning which

institutions currently have the capacity to manage groundwater is a necessary first step before making recommendations for future management options. To conduct this analysis, I applied the Conti 2014 framework by adapting the seven factors enabling transboundary water cooperation. Interviews were conducted with water managers and stakeholders in the Paseo del Norte region. Overall the findings from this research are intended to be a useful platform for decision makers to launch discourse around the sustainable use of groundwater resources.

The structure of this document is organized as follows: The remainder of this chapter provides background on the study area, the known physical properties of the aquifers, on the diverse water users, groundwater governance theory and justification of methodology. Chapter 2 dives into the specific GIS (Geographic Information System), interview and analytical methods applied. Chapter 3 conducts the institutional capacity analysis using Conti 2014 framework. Chapter 4 discusses the results and recommends options to enhance future sustainable management. Last, Chapter 5 summarizes major findings and conclusions. Throughout the entire document I used information gathered from interviews both to support my arguments and to narrow my focus on the topics stakeholders deemed important.

### **1.3 Study Area**

#### *Selection of Study Area*

There were four main criteria considered when selecting the study area. First, I sought an area that had both transboundary aquifers and potential to amend existing surface water treaties to include groundwater. My initial GIS global analysis was used to visualize areas where transboundary river basins contained treaties, which ideally could be amended to include groundwater. Second, I required an area with existing water institutions across the local, state, national, and international scales. I found the International Boundary Water Commission/ Comisión Internacional de Límites y Aguas (IBWC/CILA) is a binational effort (U.S. and Mexico) to jointly govern surface waters at the international scale. Third, the area needed to be relatively close because I intended to travel to conduct interviews. Fourth, a water scarce region was preferable because in arid regions in general people more carefully consider water supply and demand dynamics. The Paseo del Norte located in the Chihuahua desert, which receives a minute amount of annual precipitation. The quote below from the Manager of Elephant Butte Irrigation District

demonstrates how water is valued highly in an arid region. Overall, the surface water of the U.S./Mexico Paseo del Norte region is governed by the 1906 and 1944 treaties and met all of the criteria.

*“In this part of New Mexico, there is no cheap water anymore”*

(Gary Esslinger, Manager of EBID, personal communication, January 23, 2017)

For this study, *international scale* refers to the two or more countries. The national scale is referring generally to the federal scale of one domestic country. The state scale includes New Mexico, USA Texas, USA and Chihuahua Mexico. The local scale includes the cities of Las Cruces, NM, El Paso TX and Ciudad Juarez, Mexico. Throughout the Rio Grande/Bravo river basin, Mexico and the United State have different names for the same systems. Both names are used interchangeably throughout the text (Table 1). Acronyms used are located in Appendix A and a glossary of common terms are found in Appendix B.

Type of System	Mexico	United States
River	Rio Bravo	Rio Grande
Aquifer	Conejos-Medanos	Mesilla Bolson
Aquifer	Valle de Juarez	Hueco Bolson

Table 1. Names for the same resource used interchangeably throughout the text

### *Geography of Study Area*

The Rio Grande/Bravo River is the 20th longest river in the world, with a total length of 3059 km, and covering an area of 924,300 km<sup>2</sup> (Nava et al., 2016). The area of the river basin is divided almost directly in half between the U.S. and Mexico. As the river flows from the headwaters in Southern Colorado through New Mexico it forms a border between Texas and Mexico for 1,930 kilometers before terminating in the Gulf of Mexico (Schmandt, 2002). The Rio Grande/Bravo basin supports “10 million people and 121 fish species, 69 of which are found nowhere else on the planet” (Wong et al., 2007). The study area, the Paseo del Norte is located in the Chihuahuan desert, where precipitation rarely exceeds 20 centimeters annually, most of which is evaporated (Sanchez, 2006; Schmandt, 2002). Scientists warn this desert is at risk for extreme drought in the future as the impacts of climate change unfold (Gleeson et al., 2012; Dettinger, et al., 2015). The arid climate explains the relatively small amount of groundwater recharge in the basin.

Historically the Rio Grande/Bravo is characterized as a fairly ephemeral stream with periods of heavy flooding or minimal flow contingent upon the season, but it has been heavily impacted by irrigation needs over the past century. The river has been channelized, dredged, and dammed to the degree there 21 dams currently on the main stem of the river (BoR, 2013). Water flows below Elephant Butte Reservoir, New Mexico are completely controlled by the irrigation needs and the river bed is often dry during the non-irrigation, winter season. Environmental flows have historically been sidelined in favor of economic drivers of irrigation and industry (Kevin Bixby, Director of Southwest Environmental Center, personal communication, January 25, 2017). However, the federally listed endangered species, the silvery minnow, southwestern willow flycatcher, and meadow jumping mouse which depend on the riparian habitat has recently propelled action on river restoration projects and increased attention on environmental flows, especially in the Middle Rio Grande basin (Mike Hamman, Middle Rio Grande Conservancy District, personal communication, January 26, 2017). Water quality in the Rio Grande is highly correlated with the water quantity. Therefore, water quality poor during the non-irrigation season, often afflicted by high levels of salt, fecal contamination from livestock and human wastewater treatment plants, chlorides and phosphates from agriculture, and ammonia.

### *Paseo Del Norte*

The Paseo del Norte, translated to “Northern Pass” region is the case study area. While there are no definitive boundaries of the Paseo del Norte region, it is loosely defined as the binational area at the confluence of New Mexico, Texas and the Mexican state of Chihuahua (see Figure 1). The area includes the Rio Grande/Bravo River, extending 550 kilometers from Elephant Butte Reservoir in Southern New Mexico to the confluence of the Rio Conchas in Presidio County, Texas (Paseo del Norte, 2003). There are over 200,000 acres of irrigation in this region, and over 2 million people (Paseo del Norte, 2003). In this region of the Chihuahuan desert, the average maximum temperatures are 38 C (100F) (State of Chihuahua, 2010). During the 1500’s this region was named by Spanish explorers who recognized it was the only all season passage through the Rocky Mountains. Today it is still a center for trade along the U.S./Mexican border as the midpoint between the Gulf of Mexico and the Pacific Ocean. It is considered the “Upper” Rio Grande Basin as a whole but the “Lower” Rio Grande sub-basin of New Mexico.



Figure 1. Paseo del Norte region highlighted in dark orange (Hunt Institute, 2017)

### 1.3.1 Aquifers

There are three major aquifer systems in the Paseo del Norte region (see Figure 2). The Hueco Bolson is the most studied aquifer, followed by the Mesilla Bolson which was studied in the Transboundary Aquifer Assessment Program (TAAP) and the International Shared Aquifer Resource Management (ISARM) initiative (Puri and Aureli, 2009) and the Rio Grande Alluvium is the least documented, but has been studied by local and regional scientists.





Figure 2. Three principal aquifers in the Paseo del Norte region (Map created by Christina Welch using GIS shape files shared by Dr. Zhuping Sheng, Texas A&M AgriLife Research Center at El Paso)

#### *Hydrologic connectivity between the aquifers*

The hydrologic connection between the surface water and groundwater is important for management and governance designations. Section 1.5.2 expands upon the implications of connectivity for international law. It is undisputed by scientists in the U.S. that the Rio Grande river is hydrologically connected to the groundwater aquifers, though the degree of connection is debated (Hawley et al., 2004; Creel et al., 2006; S.S. Papadopoulos & Associates, Inc., 2007; Sheng, Mace, Fahy 2001). “Aquifer tests in the El Paso city well field northwest of Canutillo indicate substantial leakage between the shallow, medium, and deep aquifers” (Leggart et al, 1963 p. AA1). An estimated 33,000 acre-ft/yr of water is recharged into the Rio Grande alluvium over the Hueco Bolson (Sheng et al., 2001). The extent of the connection between the river and groundwater is so evident that in 1973 and 1998 the bottom of the Rio Grande river was lined around the El Paso-Ciudad Juarez which resulted in an immediate decline in aquifer recharge (Sheng et

al., 2001). The impacts to the river from groundwater pumping differ across time scales; often there is an unpredictable, significant lag time between pumping and stream depletion (Hathaway, 2011).

### *Recharge*

In a technical report, Witcher et al., 2004 p. 17 are careful to clarify the impact of the current climate conditions on recharge rates,

“While very large quantities (millions of AF) of fresh to slightly saline water are stored in the basin-fill aquifer system, much of it is not being effectively recharged under the warm-dry environmental conditions of the past 5 to 10 thousand years. *Current research in the region indicates that most groundwater in storage is thousands to tens of thousands of years old* and was recharged during cooler and wetter parts of Quaternary glacial-pluvial cycles” (emphasis added, Plummer et al. 2000; Scanlon et al. 2001).

### *Water Quality*

One of the primary groundwater quality concerns is the Griggs & Walnut superfund site in Las Cruces, New Mexico leaking tetrachloroethylene (PCE) a known cancer causing carcinogen, into the groundwater. In 1993 the New Mexico Environmental Department discovered the site was leaking PCE contamination into 4 of the city’s municipal wells (EPA, 2017). Currently the status is “*not under control*,” which indicates that the migration of contaminated ground water is not stabilized.” (EPA, 2017).

The study area has pockets of fresh water, but most of the groundwater is brackish or highly saline (Heywood and Yager, 2003). Other studies warn about a freshwater cap sitting on top of the denser, salty water (S.S. Papadopoulos & Associates, Inc., 2007). “Regional water experts say the freshwater cap could turn increasingly salty within 10 to 15 years and, at a minimum, that amount of time would be needed to plan and build a desalination plant that could turn the brackish resource into potable water.” (Villagran, 2016). Well abandonment due to salt water intrusion is common in this area (Heywood and Yager, 2003). Likely due in part to groundwater evaporation, there are high salt levels concentrated at the surface. The quote below explains the 150 feet of blank close to the surface is because of high salinity levels. In this farmer’s case, the deeper he drills, the fresher the water.

*“The well I put down a year few years ago is 400 feet deep. The first 150 feet are blank, that we don’t draw water from.”*

(Anonymous Pecan farmer in the Lower Rio Grande Basin, personal communication January, 2017)

Aside from the superfund site and the natural saline water, additional contaminants are fecal coliform bacteria and nitrates (Hibbs, 1999). Nitrates are found a form of non-point source pollution roughly traced back to the fertilizers and pesticides applied by farmers. Fecal coliform bacteria are caused by high density septic systems in southern New Mexico and Texas as well as the large amount of untreated sewage from Ciudad Juarez. The seriousness of the concerns from the untreated sewage dumped into the river and filtering directly into the Rio Grande Alluvium aquifer system has spurred the most recent effort by the Border Environment Cooperation Commission (BECC) to work with Mexican agencies to develop wastewater treatment plants. “Ciudad Juarez now has capacity for treating 100% of its municipal wastewater” (EPA, 2014).

## Geology

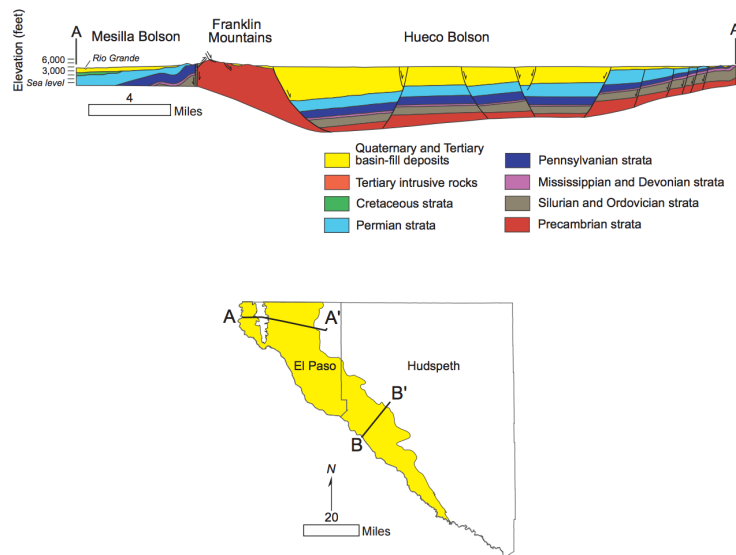


Figure 3. Geologic cross section of the Mesilla and Hueco bolsons (George et al., 2011).

The past geologic history of the Rio Grande rift affects the topographic configuration which in turn affects precipitation, ground-water recharge, source material of the basin-fill deposits, aquifer

characteristics, and ground-water quality (USGS, 2016a). The Rio Grande basin began to look as it does today roughly 4 million years ago, when increased runoff from newly uplifted geologic rift formed an integrated drainage basin (see Figure 3). The Rio Grande Basin as we know it today is part of a geologic phenomenon, a rift, which is the splitting apart of the earth's surface, in this case due to "high heat flow, late Quaternary faults, late Pliocene younger volcanoes, and deep basins" (Seager and Morgan, 1979, p. 88). The two main types of basins that formed as result of the Rio Grande Rift are classified as alluvial or bedrock. The three aquifers within the study area are alluvial basins, which consist of silt, sand, clay and gravel and often organic matter formed during the period of the Rio Grande Rift (Encyclopedia Britannica, 1998).

### *Rio Grande Alluvium Aquifer*

The Rio Grande Alluvium is a system of hydraulically connected Santa Fe basin fill deposits stretching 180,000 km<sup>2</sup> along the valley of the Rio Grande River from Southern Colorado to central New Mexico to West Texas (USGS, 2016b). Each unconsolidated alluvial deposit from the Santa Fe group ranges from a few hundred to thousands of feet deep and is part of the same formation, but differs in hydrologic and physical properties. The base of the alluvium sand, gravel, silt and clay is 18-24 meters below the valley floor, it follows the river floodplain spreading about 8 km wide, and depth to the water table is 3-8 meters below the floodplain (Garcia, 2001). There is constant interaction between the Rio Grande river and the underlying shallow unconfined Rio Grande Aquifer System, and the Mesilla Bolson (Sheng 2013 and Garcia 2001). Recharge occurs from mountain fronts and stream flow; due to the shallow nature of the aquifer, recharge from precipitation has been estimated to be 0.5 centimeters per year in areas with permeable soil (U.S. Army Corps of Engineers, 2009). Groundwater pumping from the Rio Grande aquifer is common in Colorado, New Mexico and Texas especially for shallow domestic wells. EP#1 irrigation district pumps from the Rio Grande alluvium with a total of 60 wells (Jesus Reyes, personal communication, January 26, 2017).

### *Mesilla Bolson/ Conejos-Medanos*

The Mesilla Bolson is 600 meters deep (George et al., 2011). About 40% of the aquifer lies in southern New Mexico, 10% in Texas under El Paso, and the remaining half in the Mexico (Sanchez, 2006; Hawley et al., 2000; Salas-Plata Mendoza, 2006a; Sheng, 2013). The significance of the Mesilla is the rechargeable storage capacity; it is currently being considered for artificial recharge projects on the

Mexican side (Sanchez, 2006). The estimated storage in the Mesilla Bolson is 42.9 billion m<sup>3</sup> on the U.S. side, with 97 percent found in New Mexico and the remainder in Texas (Marston and Lloyd, 2005). On the Mexican side, there is a significant area known as the Bolson de los Muertos, (the dead) where no fresh water has been found and the soil is comprised largely of clays (Marston and Lloyd, 2005.) The New Mexico Office of the State Engineer controlling extraction from the Mesilla Bolson started in the 1980's when the Lower Rio Grande Basin was declared as groundwater basin. Generally, the deeper the well the higher the water quality (Tom Blaine, New Mexico State Engineer, personal communication, January 20, 2017). Up until 2007 total withdrawals on the U.S. side were 65 Hm<sup>3</sup>/yr extracted from the Mesilla and 0.59 Hm<sup>3</sup>/yr, on the Mexican side for domestic and livestock use (State of Chihuahua, 2010). In 1997 Dona Ana County, New Mexico used 60 million m<sup>3</sup> irrigated agriculture, 24 million m<sup>3</sup> for public water supply, and 4 million m<sup>3</sup> for commercial, industrial, and mining combined (Garcia, 2015). There is a high level of uncertainty around the source of recharge, but it most likely from irrigation seepage and precipitation (Sanchez, 2006). In 2010 the new wellfield was constructed on the Conejos-Medanos aquifer and began actively pumping to supply water to Ciudad Juarez. A preliminary study has shown a drawdown of 5 meters in the water table during the summer of 2010 (State of Chihuahua, 2010).

### *Hueco Bolson/ Valle de Juárez*

The Hueco bolson is 2,700 meters deep (Sheng et al., 2001). Technically the Hueco bolson is the southern extent of the Tularosa Aquifer. However, due to the fault-bound geology of the Hueco bolson, most studies make the distinction between the Hueco bolson and the Tularosa (Anonymous researcher, personal communication, 2017). Groundwater flows from the Tularosa in southern New Mexico southward to the Hueco in Texas (Hawley et al., 2000; Sanchez et al., 2016). “The approximate volume of recoverable freshwater in the entire Hueco bolson aquifer is about 9 billion m<sup>3</sup> (7.5 million AF), with 3.7 billion m<sup>3</sup> (3 million AF) in Texas, 4.8 billion m<sup>3</sup> (3.9 million AF) in New Mexico, and 180,000 m<sup>3</sup> (600,000 AF) in Mexico” (Sheng et al, 2001; Mace et al., 2001). Recharge is about 7 million m<sup>3</sup>/yr occurring from the Organ and Franklin mountain front, seepage from the Rio Grande river, irrigation practices, and deep well injections (Sheng et al., 2001). Over the past decades, groundwater withdrawals have exceeded the recharge rate, and current withdrawals are estimated to be nine times higher than the recharge rate in El Paso County (Sheng et al., 2001). Pumping by both parties over the past 20 years has extracted 120 billion m<sup>3</sup>/yr causing alterations in groundwater flow direction, rate, quality, and land subsidence (Mace et al., 2001; Hibbs, 1999). Water table levels are currently decreasing by 1.5 to 7

meters annually (Sanchez, 2006). If current pumping rates continue, experts estimate economically recoverable fresh water from this aquifer will be exhausted between 2020-2050 (Sanchez et al., 2016).

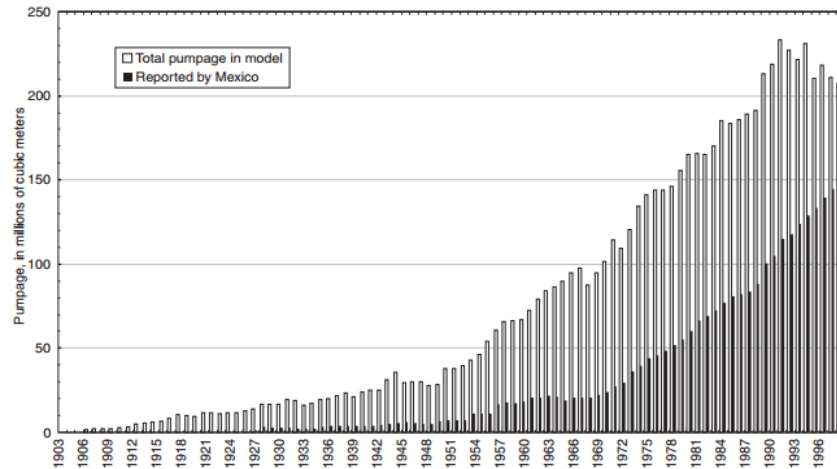


Figure 4. Hueco bolson pumping from 1903-1996. (Heywood and Yager, 2003)

The study shown in Figure 4 is comprised of “records of historical pumpage from all known municipal supply, military, industrial, and private wells” (Heywood and Yager, 2003 p.8). There has been a steady increase in pumping since the 1950’s with the majority of ground water ‘mining’ happening over the past two decades (Sansom, 2011; Turner et al., 2003). Table 2 provides a summary of the three major transboundary aquifer characteristics.

	<b>Rio Grande Alluvium</b>	<b>Mesilla Bolson</b>	<b>Hueco Bolson</b>
<b>Average Depth</b>	45 meters	600 meters	2,7000 meters
<b>Average Recharge</b>	Unknown	22 million m <sup>3</sup> /yr in El Paso County	7 million m <sup>3</sup> /yr
<b>Average Withdrawal</b>	Unknown	U.S. side 65 Hm3/yr	120 billion m <sup>3</sup> /yr total
<b>Confined</b>	Unconfined	Confined	Confined
<b>Age of Water</b>	Unknown	Unknown	12,100- 25,500 years.
<b>Water table drawdown</b>	Unknown	Unknown	1.5 to 7 meters annually

Table 2. Compilation of Known Aquifer Characteristics (Sanchez et al., 2016; Leggat et al., 1963; Guiterrez, 2000; Plummer et al., 2000; Heywood and Yager, 2003; Chávez, G, Klein 2000; Sheng et al., 2001; George et al., 2011; Mace et al., 2001; CONAGUA, 2009)

## 1.4 Background:

### 1.4.1 Groundwater Users

Extraction of groundwater at a rate that exceeds the rate of recharge causes a cone of depression, or a dry funnel which can span from a few feet to hundreds of feet (USGS, 2016a). Similar to a bathtub drain effect, the surrounding groundwater will start to flow towards the well, draining the water in the immediate area, often driving the need to drill deeper wells. In extreme cases, pumping of groundwater can increase the amount of surface water percolating into groundwater to replenish the natural water table levels (USGS, 2016a). This is most likely the case in many parts of the River Grande basin, especially under the cities of El Paso and Ciudad Juarez where the cones of depression are up to 60 meters (200 feet) deep (Heywood and Yager, 2003). Noticeable effects of groundwater pumping are: surface springs drying up, streams and rivers becoming noticeably smaller or drying up completely, land subsistence, deterioration of water quality, and increased pumping costs (Glennon, 2002 and Konikow 2013). Eckstein 2011 p. 284 summarizes the situation along the border as such, “Locals on each side of the border have constructed wells and are withdrawing groundwater in response to increasing demands of population growth and economic development, with little regard for the consequences of their independent or collective actions on the region’s transboundary aquifers.”

### *Population*

There are over 2 million people inhabiting the cities of El Paso and Ciudad Juarez, divided 730,000 and 1.5 million respectively (Carter et al., 2015 and Dettinger et al, 2015). The population of Dona Ana County, New Mexico in 2013 was estimated at 213,460. (Dona Ana County, 2014). Population rates are projected to continue increasing for Ciudad Juarez, New Mexico, and Texas (Peach and Williams, 2000).

### *Per Capita Water Use*

Table 3 display the vast contrast in water use between El Paso (population 730,000) and Ciudad Juarez (population 1,300,000) (Marston and Lloyd, 2005). “Between 1980 and 1990 the per capita municipal and industrial use of water in El Paso has been reduced from 757 liters per day (lpd) to a current 620 lpd. This has been achieved largely through voluntary water conservation measures” (Marston and Lloyd, 2005). During the same period, water use in Ciudad Juarez increased 40% to 378 lpd which was achieved by an increase the percentage of homes that have inside plumbing and an increase in commercial and industrial demand (Marston and Lloyd. 2005). Regardless of the recent increase, the average person in El Paso is

still using nearly double the amount of water daily as a resident in Ciudad Juarez. This explains why even though Ciudad Juarez has nearly double the population, the overall water use between the two cities is about the same (see Annual Municipal and Industrial Use, Table 3).

	City & County of El Paso Texas	Ciudad Juarez	Total
Per capita Municipal & Industrial use (liters/day)	620	378	998
Annual Municipal & Industrial use (million m <sup>3</sup> /year)	165	179	334
Agricultural (million m <sup>3</sup> /year)	412	230	642

Table 3. Current Water Demand El Paso and Ciudad Juarez (adapted from Marston and Lloyd, 2005).

Many people along the Texas border are paying a large portion of their income for water (Kelly, Bulletin 107). In contrast, “In Mexican cities, water has been largely free in the past and there is public resistance to paying for water service, linked largely to doubts about the reliability of the service and concerns about transparency in municipal management of revenues” (Kelly, Bulletin 107).



### 1.4.2 Groundwater Uses

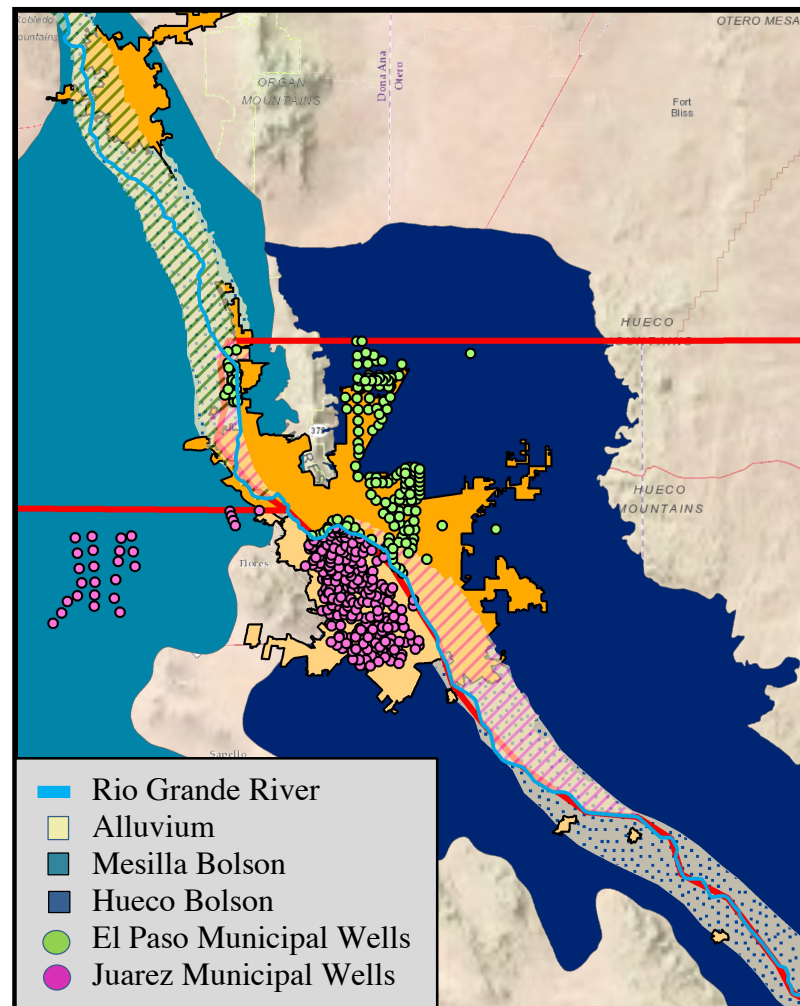


Figure 5. Municipal wells Ciudad Juarez and El Paso (Map created by Christina Welch using data from New Mexico State Water Resources Research Institute, 2015; Valle-Jones, 2013; Dr. Sheng Texas A&M AgriLife Research Center at El Paso; New Mexico OSE, 2017; TCEQ, 2016)

#### A. Domestic

There are three major well fields in the study area. Figure 5 displays the overlap between the aquifers, the cities, and the municipal wells. The hashed pink line represents the El Paso #1 irrigation district and the green hashed line represents the Elephant Butte Irrigation District. The municipal well fields are represented by the highest cluster of green and pink data points. There are three major well fields in the Paseo del Norte region.

1. **Canuillo, Texas:** EPWU's well field produces approximately 30 million m<sup>3</sup> of water annually, supplying nearly 20 percent of El Paso's total water demand (Hamlyn et al., 2002).
2. **Santa Teresa, New Mexico:** Commonly known as the industrial park, it is the site of the \$400 million dollar Union Pacific inter modal hub, and the center for much of the industrial and economic trade between the U.S. and Mexico (Ciudad Juarez-Chihuahua News, 2007). There is a separate border crossing between Santa Teresa and Mexico. There is no public information available on the amount of wells and pumping taking place here.
3. **San Jeronimo, Mexico:** To the south, aggressive pumping by the Junta Municipal de Aguas y Saneamiento (JMAS) in the central area of Cd. Juárez is causing a net movement of groundwater from north of the international border to the well field in Cd. Juárez. (Hamlyn et al., 2002). The newest wellfield is drawing from the Conejos-Medanos/Mesilla Bolson. In 2010 there were 23 new wells constructed with the capacity to pump 1,000 liters per second in the Conejos-Medanos aquifer along the Mexican side of the border (Ciudad Juarez-Chihuahua News, 2007). The wells are connected to a 23 kilometer conveyance pipe which supplies water for municipal purposes to Ciudad Juarez.

#### *Lower Rio Grande Basin, New Mexico*

New Mexico Office of the State Engineer (OSE) reports there are 17,248 total wells in the Lower Rio Grande Basin. Active wells account for 8,475 of the total wells, with an overall appropriation of about 300,000-350,000 AF of groundwater annually (Tom Blaine, New Mexico State Engineer, personal communication, January 20, 2017).

#### *City of Ciudad Juarez, Mexico*

The 60,000 AF (74 million cubic meters) of Rio Grande surface water allocated to Mexico under the 1906 Convention is used solely for irrigation water for the farmers in Ciudad Juarez (Gutierrez, 2000). Hence, the city relies entirely on groundwater for domestic drinking water supply. Ciudad Juarez has depended on the Hueco bolson aquifer for the city's 1.5 million residents until a few years ago with the installation of the Conejos-Medanos wellfield (Carter et al., 2015). About 92% of the total population is connected to the JMAS system which owns more than 192 municipal wells with average depths from 200- 400 meters

and (Gutierrez, 2000; Turner, et al., 2003). In Ciudad Juarez agriculture accounts for 3%, manufacturing accounts 43%, commerce 16% of the total employment (INEGI, 2000).

### *El Paso, TX*

Until the late 1990's El Paso also used the Hueco bolson for the main source of drinking water (TCEQ, 2014). Since then, they have actively diversified their water sources by pumping from the Mesilla (20%) Hueco (40%), and the remainder from the Rio Grande river (EPWU, 2007). While the city of El Paso has constructed one of the largest inland desalination plant in the world (Hathaway, 2011), Ciudad Juarez, Las Cruces and the Fort Bliss Military Reservation still depend 100% on groundwater (Sheng, 2013; Evans, 2006). In 2007 the largest inland desalination plant in the United States was constructed in anticipation of decreasing water quality from the Hueco bolson (TWDB, 2014). Given the estimations of water running out in the Hueco, the Mesilla has become the next best option for an alternative water supply source (CONAGUA, 2009; Hathaway, 2011; Sanchez et al, 2016).

### **B. Agriculture**

Agriculture accounts for 70-75% of the water use on the U.S. side of the border (Kelly, Bulletin 107). There are many factors that play into farmers deciding to pump groundwater or use surface water. John Fleck, Director of University of New Mexico's Graduate Water Resources Program stated, farmers prefer to use surface water instead of groundwater because it's cheaper, they don't have to pay to pump, and because of generally higher quality (personal communication, January 23, 2017). This statement was echoed by many water managers in the basin throughout my interviews although an anonymous pecan farmer in the Lower Rio Grande Basin added, "That choice is decided first by the availability of surface water, and second by the requirements of the water administration in New Mexico" (personal communication January 2017). In general, surface water is a first choice for many farmers, but increasingly, groundwater pumping supplements surface water allocation in years of surface water scarcity.

The groundwater sources for agricultural pumping on the U.S. side are the Rio Grande Alluvium and the Mesilla bolson. Intensive pumping on the U.S. side of the border started in the 1950's due to combination of the growth of the agricultural industry and extreme drought. However the expansion of Mexican agriculture occurred a bit later between 1970 to 1994 in the states of Tamaulipas and Chihuahua (Carter et

al, 2015). The difference is most of the agriculture in Ciudad Juarez depends on surface water, while the U.S. farmers have been intensively pumping groundwater for over 50 years.

Over the past 40 years the farmers in New Mexico and Texas have shifted from lower value crops to higher value crops. This has been a result of both the high price of the pecan market in China and the state offering subsidies for pecan farmers (Mike Hamman, Middle Rio Grande Conservancy District, personal communication, January 26, 2017). Consequently, there are now less cotton and chili peppers and more pecans and alfalfa (Adrian Oglesby, Middle Rio Grande Conservancy Board Member and Director of Upton Transboundary Resource Center, personal communication, January 20, 2017). This becomes a unforeseen problem because the pecan orchards use exponentially more water year round than chili and onions.

### **C. Industry**

From 1980 to 2000 the number of maquiladora plants in Juarez nearly tripled from 121 to 312 (Kelly, Bulletin 107). Maquiladoras are the name for the industrial factories which have proliferated on the Mexican side of the border as a result of NAFTA (North American Free Trade Agreement). In 2012 there were 178,900 employed in the maquiladora industry in Ciudad Juarez, and 252,386 people in the state of Chihuahua (BorderPlex Alliance, 2012).

### **D. Military**

The strong military presence in Fort Bliss is spread throughout 1.1 million acres of land in Texas and New Mexico (Military Installation, 2017). Fort Bliss is comprised Army and National Guard with a total population of 166,292, about 30,000 of which are active duty military (Military Installation, 2017). Information is not available on how much Fort Bliss pumps, only that it is 100% dependent on groundwater (Department of Defense, 2005).

### **E. Culture**

In Dona Ana County, New Mexico 66.4% percent of the population is of Hispanic origin and in El Paso County 81% is of Hispanic origin. (Dona Ana County, 2014; U.S. Census 2015). There are close cultural ties between the two cities of El Paso and Ciudad Juarez, and thousands of people cross the border every day to commute to work (Rice 2011).

*“There’s a big issue with groundwater pumping in Ciudad Juarez and El Paso. There’s going to have to be some major work done there to figure out what would be a fair allocation of that water so they don’t pump themselves into oblivion with those aquifers.”*

(Mike Hamman, personal communication January 26, 2017).

In summation, the three aquifers in the Paseo del Norte region vary in capacity but are geologically similar. In terms of water demand, the total municipal and industrial demand for El Paso and Ciudad Juarez makes up about 25% of the total demand. However industry supplies 60% of the jobs in the region (Marston and Lloyd, 2005). In contrast, agriculture accounts for 75% of the total demand, while it provides 5% of employment (Wheat 2015; Marston and Lloyd, 2005). The demand for water is heaviest on the U.S. side from the agriculture, and on the Mexican side from industrial use. There are major pumping restrictions on the New Mexican side which started with the State Engineer’s declaration of the basin in 1980 (Tom Blaine, New Mexico State Engineer, personal communication, January 20, 2017). However, there are currently no pumping restrictions in Texas and little enforcement of permits in Mexico.

## **1.5 Groundwater Governance**

Groundwater governance can broadly be conceptualized as the theoretical/legal/social underpinnings which guide water management practices. It is crucial to critically consider the reasons behind how and why water management decisions are made. Because transboundary aquifer management is an emerging paradigm, when shaping the future direction ethical morals and legal principles can be drawn upon to guide future management. Within water governance theory, the topics to be further discussed relevant to this research are: groundwater as a common pool resource, integrated water resource management, and top down vs. bottom up management, United Nations Conventions, and existing groundwater treaties.

### **1.5.1 Theory and Practice**

“Scholars are slowly shifting from positing simple systems to using more complex frameworks, theories, and models to understand the diversity of puzzles and problems facing humans interacting in contemporary societies” (Ostrom, 2010 p. 641). Groundwater governance is one of these new concepts.

There is not one universal definition of governance, water governance, or groundwater governance specifically. In Mexico, water governance is defined as, “a means that allows achieving objectives, where the different stakeholders are involved and in a participatory approach between the water managers and the water users” (Castro, et al., 2014 p. 3). While this definition focused primarily on the equitable distribution of water, the definition from Pahl-Wostl et al., 2008 accounts for larger social constructs. Water governance is “the range of political, social, economic and administrative systems that are in place to regulate the development and management of water resources and the provisions of water services at different levels of society” (Roger and Hall, 2002).

There are few key characteristics which make the management of groundwater distinct from the management of surface water, or any other natural resource. Steven Solomon is not the first to point out the price of water does not reflect the true irreplaceable value (Solomon, 2010). Like any resource it can be captured, bottled and sold for a profit. Unlike any other minable resource, it is absolutely essential for human life.

#### *Groundwater as a common pool resource*

Groundwater is a common pool resource which means "enjoyed by everyone... but can never be acquired as a whole" (Araral, Black Dictionary of Law, 1990). There are four applicable theories relevant to governing common pool resources. First, Hardin 2009 famously proposed the theory of tragedy of the commons, in which individuals sharing a common pool resource will always act independently with their own self-interest in mind, ultimately depleting or spoiling the resource through collective action. Why conserve water if the same water source can be captured and used by someone else? (Schlager, 2007). Mirroring Hardin's tragedy of the commons is the Malthusian belief the Earth's carrying capacity for resources essential for human life has been far exceeded by population growth (Ehrlich et al., 1993). Third, the other extreme opposing the Malthusian paradigm is the Cornucopian theory, named from the proverbial “horn of plenty.” (Simon, 1996). This theory states natural capital is easily substituted for other forms of capital, with the primary implication being that the evolution of technology will sufficiently take care of problems caused by population growth (Simon, 1996).

Fourth, equally prominent in literature is Ostrom's dissertation which debunked the tragedy of the commons with a small-scale case study of groundwater use in California. Ostrom proposes that common pool resources can indeed be sustainably managed (Ostrom, 2001). Her seminal dissertation paved the

way for what later became the famous Institutional Analysis and Design framework, which has reframed how scholars examine institutions today (Araral). She makes the distinction that groundwater as a common pool resource, is both non-excludable and rivalrous (or subtractable) (Schlager, 2007). Specifically, is impossible to exclude others from using groundwater (non-excludable) and using the resource make it unavailable to others (rivalrous) (Ostrom, 2010). Because the groundwater is connected, albeit to varying degrees, often one stakeholder's use of water affects all the others in the immediate surrounding area. The non-excludability, rivalrous nature of water makes it difficult to govern as a common pool resource. When applied to Paseo del Norte case study, a representative from the Texas Commission Environmental Quality (TCEQ) said, "Because those aquifers are shared with New Mexico and Mexico, it's a political nightmare. No politician wants to touch that." (Anonymous interviewee, personal communication, April 2017). However, Ostrom 2001 argues that water users are likely to invest in adopting rules to govern common pool resource if 1) the benefits to the rules outweigh the cost of planning, monitoring and implementation 2) they themselves will enjoy the benefits.

#### *Integrated Water Resource Management (IWRM)*

According to the United Nation's Water for Life program, "IWRM approach has now been accepted internationally as the way forward for efficient, equitable and sustainable development and management of the world's limited water resources." Although IWRM has become a widespread, rational appeal by water managers, issues of implementation and legality of existing regimes render it largely idealistic (Blomquist and Schlager, 2005). For example, the Global Water Partnership's definition of IWRM as, "maximizing the economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (United Nations Water for Life, 2014) while inspirational seems borderline contradictory and unlikely to achieve in practice.

There is a large gap between IWRM theory and actual practice, for which politics are usually blamed (Blomquist and Schlager, 2005). Often the key of successful watershed management relies on "the degree of political commitment to the objectives by those who have authority to act. Regrettably, science can offer no help in this problem" (Pereira, 1989 p.54). Intrinsically, the "management" of water resources is purely a social construct. How we choose who gets what, when and where are largely social, power dynamics instead of physical or rational decisions. Supporting the theoretical foundation for my research, Blomquist and Schlager, 2005 p.102 propose "fundamental political concepts of boundary drawing and

decision making may be used to understand the gap between integrated management prescriptions and polycentric practices.”

Two popular tenants of IWRM are- water resources should be managed according to the hydrologic boundaries at the watershed scale, and by a joint governing body (Blomquist and Schlager, 2005). In the Rio Grande Basin, the IBWC-CILA functions as a joint surface water governing body. Additionally, I found through my interviews the water managers in the basin largely agreed both surface and groundwater should be managed according to hydrologic boundaries. The physical boundaries of the resource hold a privileged status that transcends other arbitrary human created borders (Blomquist and Schlager, 2005). However, Blomquist and Schlager, 2005 p. 102 found “as a unit of organization, *the watershed* does not resolve fundamental political questions about where the boundaries should be drawn, how participation should be structured” and who should be held accountable. While this concept of managing water according to natural boundaries is appealing and rational, when considering implementation to each resource in conjunction with existing human created boundaries, the task becomes quite complicated. For example, forests ecosystems, aquifers, and watersheds each have different boundaries. Place the geo-political boundaries over these and suddenly the mosaic of existing legal regimes, diverse water users and cultural practices comes alive. My research navigates through this institutional web. I found true to the literature, the concepts of IWRM are well established among the water managers and professors in the Paseo del Norte. Equally so, the paradigm of managing water by the hydrologic boundaries has proved challenging to implement in the over-allocated, transboundary Rio Grande River basin.

### *Top-down, Bottom-up, and Polycentric Governance*

“There is some disagreement as to whether rules on transboundary aquifer management should be developed at the global level, or if they would be more effective if developed at the level of specific aquifers.” (Eckstein and Sindico, 2014 p.37). Regional scale scholars argue each aquifer is unique in geomorphology, recharge, discharge and subterranean water flow directions. As such, it is necessary to have a tailored agreement that adequately addresses these physical characteristics as well as the social and cultural norms for the area (Gabriel Eckstein, personal communication, February 28, 2017). Conversely, others argue a top down treaty, or government enforcement mechanism is necessary to regulate groundwater abstraction.



This dichotomy of top down vs. bottom up governance is a fundamental aspect of the scalar analysis of this research. Pahl-Wostl, 2007 proposes a third option. There is a paradigm shift occurring in water resource management in which traditionally hierarchical, top down government authority is shifting not to bottom up, but to a more multi-scale, multi-stakeholder approach, coined polycentric governance (Pahl-Wostl, 2007; Pahl-Wostl et al., 2007). Polycentric governance systems are defined as “complex, modular systems where differently sized governance units with different purpose, organization, spatial location interact to form together a largely self-organized governance regime” (Pahl-Wostl, 2009 p357). Instead of top down vs. bottom up, my research adopts the web of polycentric governance as the cornerstone within the assessment of water management across scales. I acknowledge the various scales of water governance are constantly interacting. My research attempts to untangle the web of polycentric governance to identify the key connections among the water managers on each scale.

### *Managing Groundwater with Uncertainty and Risk*

How humans react to risk, uncertainty, and scarcity is often irrational and fraught with implicit biases (Tversky and Kahneman, 1975). Recent research proves depending on whether or not the uncertainty develops over a short time period or long time by learned associations, the brain uses two completely different physical parts and mechanisms to make these decisions (Huettel et al., 2005). Tversky’s and Kahneman’s prospect theory suggests evaluations of outcomes under uncertainty are highly dependent on prior observations for a reference point (Osberghaus, 2015). However, climate change effects are predicted to be beyond anything we have experienced thus far, thereby rendering our mode of reference irrelevant. Not having a platform of knowledge in which to predict what is going to happen changes how we make decisions. It becomes more difficult to plan for long term sustainable measures when short term emergencies take priority.

### *Conflict and Cooperation*

Faced with a highly uncertain future, some scholars observed the media and academic literature claims the cause of the next global crisis to be over fresh water (Postel, 1999). In his recent book, Steven Solomon precariously predicts countries with a combination of water scarcity, nuclear arms, and political instability could culminate into drivers of future conflict (Solomon, 2010). However, research by Wolf 1998 and 2007 found there have been more instances of cooperation than conflict over water resources. Throughout human history, the only known war over water was 4,500 years ago between two

Mesopotamian city-states (Wolf et al., 2003). Zeitoun and Mirumachi, 2008 find middle ground by proposing both cooperation and conflict are occurring simultaneously, albeit to varying degrees.

### *Institutional Capacity*

Institutions are touted in academic literature as a key indicator for how wells basins can adapt to climate change impacts (Willems, et al., 2003; Wolf et al., 2003). Of key significance to this research, the institutional capacity to absorb changes can be a potential indicator for cooperation or conflict within a water basin (Wolf et al., 2003). Extreme drought in the Rio Grande basin has exposed a lack of institutional flexibility (Garrick et al., 2016) which demonstrates governance regimes are not currently prepared to deal with future uncertainty (Pahl-Wostl 2009).

*“The likelihood and intensity of dispute rises as the rate of change within a basin exceeds the institutional capacity to absorb that change.” (Wolf et al., 2003 p.43).”*

Specifically, Wolf et al., 2003 found the greater the capability of the institutions to adapt to change, the more likely cooperation over water will be. Functional institutional capacity can be defined as, “existence or absence of joint water management bodies or treaties, general friendship/hostility over non water issues, and stability and types of governments within a basin” (Wolf et al., 2003 p. 42). For this analysis prior cooperation over water resources is an indicator which contributes to the overall assessment of institutional capacity, which in turn informs how likely the basin is to cooperate over future water resources. Institutional capacity is a valuable measure that is not a solution for uncertainty, but instead it can be a useful predictor of future issues.

### *Sustainability*

Sustainability implies renewability, a false association. The literature explains the “safe yield” as “the development of a ground-water system is considered to be “safe” if the rate of ground-water withdrawal does not exceed the rate of natural recharge” (Alley et al. 1999). The concept of safe yield has been recognized as a myth due to oversimplification of many complex discharge and recharge mechanisms that contribute to understanding the entire aquifer system (Alley et al. 1999 p. 15; Ponce 2007).

Of key importance for this research is understanding that the definition of *sustainable* differs among stakeholders, communities, and individuals. The Texas Water Development Board defines the annual

ground water “available” as the amount of recharge to the aquifers (TWDB, 1990). When *sustainable management* is used throughout this document, this research adopts the Alley et al. 1999 definition in that, “the use of groundwater can be maintained for an indefinite time without causing unacceptable environmental, economic, or social consequences.” While “indefinite time” is very broad, for this research, sustainable management would include any measure that increases the longevity, or life of the fossil aquifers.

*“Before creating an agreement, it is important to agree on what sustainability will mean for each of the states, and Mexico.”*

(John Fleck, University New Mexico Director Water Program, personal communication January, 23, 2017)

The concept of equitable distribution is both a pillar of IWRM and a founding principle of the polycentric governance mode (Pahl Wostl, 2007). Equality and equity are often confused. For example, equality is every person in a room receiving the same size piece of pie. On the other hand, equity would manifest as distribution depending on that person’s size where the biggest person receives the biggest slice of pie, and the smallest person, the smallest piece. Equitable distribution is recognized through international acceptance of the 1997 Watercourses Convention, 2008 ILC Draft Articles (Jorge Salas-Plata, Universidad Autonoma Ciudad Juarez, personal communication, April 2017).

Equitable management and fairness is critical to consider in the context of this research. Specifically, Juarez has double the population of El Paso but per person/day, uses half the amount of water. How is equitable distribution of ground water determined in this situation? When making a treaty, who gets rights to how much water? What is fair? Is it necessary to allocate percentages to each side of the border? This research suggests these as questions should carefully be considered by those making a potential agreement, but I do not attempt to answer the questions in this study.

### 1.5.2 United Nations

There has been a scattered progression of efforts by the international community and the United Nations to universally recognize the importance of shared groundwater resources. Thus far, the 2016 Sustainable Development goals include transboundary groundwater, and Table 4 outlines the progress made through conventions and agreements the past century.

### *Sustainable Development Goals*

**SDG Indicator 6.5.2:** Proportion of transboundary basin area with an operational arrangement for water cooperation.

(United Nations Statistics, 2016 p.26)

In 2015 the United Nations adopted 17 Sustainable Development Goals (SDG's) with the intention of worldwide implementation by 2030. The goals expanded upon the Millennium Development Goals and are a call to action to improve the lives of people around the world. These goals are a platform for global recognition of many issues facing today's world. Specifically, Sustainable Development Goal #6 is to ensure availability and sustainable management of water and sanitation for all. Each goal has specific targets and each target has indicators for measuring the implementation of the goal. Relevant to this research is target 6.5 "By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate" (United Nations Statistics, 2016 p. 26). The indicators to measure this target are include 6.5.2 (see above box).

The global map developed by this research can aid in the visualization of indicator 6.5.2. depending how "operational arrangement" is defined. The United Nations defines an *agreement* as an institutional arrangement and/or an established organization provides a framework for cooperation on transboundary water management e.g. a treaty, convention, Memorandum of Understanding (United Nations Statistics, 2016 p. 26). *Operational* in this context is defined as "regular meetings of the riparian countries to discuss the integrated management of the water resource and to exchange information" (United Nations Statistics, 2016 p. 26). While research by McCracken 2017 further expands upon definitions of operational arrangement, this research only considers international treaties due to time constraints. Therefore, this research conducted a spatial global analysis using GIS to find the proportion of transboundary area covered by a treaty or "operational arrangement."

### *Applicable Conventions*

It is important to note the process of legality involved with signing a convention. When a nation signs on to a convention, it does not become legally binding until the nation "takes the additional step of ratifying, accepting, approving or acceding" through its domestic government (IWLP, 2015). Neither the United States nor Mexico have signed onto the 1992 UNECE or 1997 Watercourses Conventions.

Document	Relevance to Groundwater
1911 Madrid Declaration	The first effort by international organizations to codify principles of international freshwater management. (Madrid Declaration, 1911)
1966 Helsinki Rules	The first international recognition of transboundary waters. This is evident in Article II, where International Drainage Basins are defined as a “geographical area extending over two or more States...including surface and underground waters flowing to a common terminus.” (Helsinki Rules, 1966 Article II)
1972 Stockholm Declaration	The first environmental conference that recognized the human-water interaction and created norms for water management (Conti and Gupta, 2016).
1986 Seoul Rules	First international effort to recognize transboundary groundwater, specifically confined aquifers (McCaffrey, 2007) “the waters of an aquifer that is intersected by the boundary between two or more States [...] whether or not the aquifer and its waters form surface waters part of a hydraulic system flowing into a common terminus” (Seoul Rules, 1986 Article I).
1989 Bellagio Draft Treaty	Created to provide a framework for future treaties on transboundary groundwater (Utton and Hayton, 1989)
1992 Rio Declaration	Created the framework for 27 environmental principles that are largely still used today (Rio Declaration, 1992)
1992 UNECE Convention	The first international joint effort to connect human health with proper management of transboundary ground water. Article 1 defines, “ground waters...which mark, cross or are located on boundaries between two or more States” (UNECE 1992: Art. 1.1). It has been in force since 1996 and is legally binding on its signatories.
1997 Law of Non-Navigational uses of International Watercourses	The result of a 30-year project to create a legally binding water law framework by the UN’s ILC. It entered into force in 2014. It is one of the only legally binding agreements for water resources. The Convention defines surface and <i>connected</i> groundwater as a system (United Nations Watercourses Convention 1997, Article 2a). However, it does not include confined, fossil aquifers which lack a hydrologic connection to surface water.
2008 Draft Articles on the Law of Transboundary Aquifers	An effort to address confined aquifers. Here an aquifer is defined as “a permeable water-bearing geological formation underlain by a less permeable layer and the water contained in the saturated zone of the formation” and include all aquifers where its “parts ... are situated in different States” (United Nations ILC Draft Articles 2008: Art. 2a, 2c).

Table 4. Timeline of International Instruments with Transboundary Groundwater Implications

### *Hydrologic connection*

The connection between surface water and groundwater has been established by scientists globally (Alley et al, 1999). Lakes, rivers, wetlands and other surface water features interact with groundwater in various forms of recharge and discharge (Winter 1998). As such, pumping of groundwater almost always decreases the amount of surface water available.

International law has made the distinction between confined and unconfined aquifers for legal/management purposes. Jurisdiction is contingent upon the hydrologic connection between the groundwater bodies. “There is a growing recognition that shallow aquifers may potentially be managed differently than deeper aquifers” (Lopez-Gunn and Jarvis, 2009 p. 744). The Draft Articles and Berlin Rules are the only two documents which specifically define an aquifer in terms of the entire systems, effectively including both confined and unconfined aquifers (Gupta and Conti 2016; Eckstein 2007; UN ILC 2008). However, the United Nations Watercourses Convention and Helsinki Rules provide more general definitions that focus inclusively on groundwater that is hydrologically connected to the surface water (Gupta and Conti 2016). Though there is not a universally recognized depth at which groundwater is connected to surface water, the groundwater model built by Haitjema & Mitchell-Bruker 2005 suggest a threshold of 305 meters. Lopez-Gunn and Jarvis 2009 propose an additional parameter, by characterizing groundwater according to the maximum pump lift capacity of 550 meters. The deeper systems could be deemed separate from the watershed or even “considered part of a larger commons” (Lopez-Gunn and Jarvis, 2009 p. 747). International law has taken strides in distinguishing groundwater for management purposes, but the work is far from done. Next steps would include more specifically defining confined and unconfined aquifers and considering other ways of measurement, like lift capacity.

### *Draft Articles*

The most recent international movement on transboundary aquifers was the Draft Articles. Although the member States and United Nations General Assembly has given considerable attention to principles of the Draft Articles, there has not been consensus reached by the international community on how to move the principles forward (Eckstein and Sindico, 2014). The debate is the uncertainty over the next step for the Articles, whether or not they should be a declaration of principles, an international framework, or if they stay simply as a legally non-binding document (Conti and Gupta, 2016). The key points of the discord among the Draft Articles are national sovereignty and significant harm. Instead of reaching a consensus between nations on groundwater principles “an intergovernmental process could open a Pandora’s box of

substantive dissent that might lead to a watering down of the existing Draft Articles” or simply no agreement (Eckstein and Sindico 2014 p. 36) The contention over the next step for the draft articles reflects the uncertainty over how groundwater should be governed on the international scale. Although the theory behind groundwater governance has been evolving, the legal mechanism and governmental capacity to govern groundwater does not commensurate the current knowledgebase.

### 1.5.3 Principles of International Water Law

During the 1990’s and early 21<sup>st</sup> century, customary law principles transitioned from primarily surface water to begin including groundwater. Today we find ourselves in the early stages of creating groundwater agreements at the international scale. “Groundwater resources historically have been omitted from, or neglected under, international law and cursorily misunderstood within the legal community” (E. Eckstein and Y. Eckstein 2003 p. 222). The International Court of Justice’s Article 38(1b) recognizes the Court shall apply customary laws as “international custom, as evidence of a general practice accepted as law.” (McCaffrey 2006 p. 45). These principles are not always legally binding and they are continually evolving concurrently with the international discourse and popular opinions at that time.

The pillars found within customary transboundary groundwater law are:

**Duty to cooperate-** includes the duty to exchange data and information and to provide prior notification of planned new uses

**Prevent significant harm-** the duty to take all appropriate measures to prevent the causing of significant harm to other watercourse (aquifer) states.

**Equitable and reasonable-** the right to utilize an international watercourse (aquifer)

(McCaffrey 1987; Conti & Gupta, 2016)

Additional principles include data sharing, which is the foundation for cooperation and common understanding leading to the protection of water resources and sustainable economic development (Callegary et al., 2016). “Transboundary water availability issues require sharing hydrologic data across political boundaries. However, national hydrological records are often withheld for political, socioeconomic, and defense purposes, complicating regional water management discussions” (Famiglietti and Rodell 2013).

There is not a comprehensive agreement on groundwater that takes into account all of these principles. One of the reasons is a number of the principles are contradictory. For example, the human right to water and using water for economic use are not possible simultaneously. Because the international principles of water law must be broad enough for all countries to agree, the general nature leaves them open for different interpretation in each country. The manner in which each country translates the principles into legislation and institutions is highly dependent on the cultural interpretation, political dimensions and geographic location. Conti and Gupta 2016 found that the principles that have evolved in groundwater governance do not sufficiently address the link between groundwater resources and all water resources, how climate change could impact groundwater, and how trade could affect the equitable sharing of groundwater.

The following principles in Figure 6 and Table 5 are not a comprehensive list of all of the legal principles that could be applied to groundwater governance. It is a review of what has been used in legal texts, declarations, and treaties thus far.

### *Precautionary principle*

The precautionary principle was mentioned in the Rio Grande Declaration, but it has been slow to be accepted as a customary principle of international law. It is defined by example as, “a State interested in undertaking or continuing a particular activity has to prove that it will result in no harm, rather than the other side having to prove that it will result in harm.” (Ireland v. United Kingdom, 2002). This principle was included in the Minute 242 addendum to the 1944 Treaty.

“With the objective of avoiding future problems, the United States and Mexico will consult with each other prior to undertaking any new development of either surface or groundwater resources, or undertaking substantial modifications of modern developments, in its own territory in the border area that might adversely affect the other country.” (IBWC, Minute 242, Resolution No. 5, 1973).

Although this was written in 1973 the precautionary principle has remained no more than a theoretical principle within the Rio Grande/Bravo basin. Although both sides of the border are aware of the precautionary principle, no further action to implement this paradigm can largely be attributed to differing priorities, budgets, and cultural perspectives on water.



Document		Exchange of information	Peaceful resolution of disputes	Sovereignty	Equitable and reasonable use	No priority of use	Polluter pays	Precautionary principle	Aquifer/Basin as management unit	Monitoring	No significant harm
1966	Helsinki Rules		X		X	X	X		X		
1992	Dublin Statement										
1992	Rio Declaration		X	X			X	X			X
1992	UNECE Convention	X	X		X		X	X	X	X	X
1997	UN Watercourses Convention	X	X		X	X			X		X
2004	Berlin Rules	X	X	X	X	X		X	X	X	X
2008	ILC Draft Articles	X		X	X			X	X	X	X

Figure 6. Applicable Groundwater Principles (adapted from Conti and Gupta, 2016)

Principle	Definition
Exchange of information	Share relevant information
Peaceful resolution of disputes	Settle disputes through negotiation, mediation, conciliation, consultation, arbitration or tribunal.
Sovereignty	Countries act as they wish within territorial boundaries
Equitable and reasonable use	Share transboundary water based on each other's conditions
No priority of use	Recognize there is no inherent priority of use for water
Polluter pays	Recognize the polluter internalizes the cost of pollution
Precautionary principle	Take precautionary action to prevent irreversible harm even when there is inconclusive scientific evidence
Aquifer/Basin as management unit	Use the water basin as a unit for policy making and implementation
Monitoring	Monitor both groundwater quantity and quality
No significant harm	Not cause harm to other states; this limits sovereign rights of states

Table 5. Explanation of Principles

*Absolute territorial integrity vs. absolute territorial sovereignty*

The paradigm of absolute territorial sovereignty was largely propagated by the Attorney General of the United States in 1894, Judson Harmon. During this time the Mexican Minister Matias Romero, filed a complaint that increased irrigation in Colorado and New Mexico “seriously affected the existence of frontier communities for several miles below Ciudad Juarez.... to point out the danger lest otherwise these communities may be annihilated.” (Letter from Romero to Gresham, 1894). Mr. Harmon’s response was that the United States is entitled to the sovereign right to allocate all water within territorial boundaries with complete disregard to downstream users (Utton, 1996). Thus the “Harmon Doctrine” was born, a paradigm which has become largely known worldwide as absolute territorial sovereignty. However instead of acceptance, there are far more examples where this doctrine has been “universally repudiated in international law, U.S. law, and ethical codes” (Gleick, 2009; McCaffrey, 1996; Wheat, 2015). Interestingly, even though the Harmon Doctrine originated in the Rio Grande Basin, for the past century instead of being accepted, the mentality of sovereign right to not share has been reversed, as exemplified by the signing of the 1906 Convention and 1944 Treaty between the U.S. and Mexico.

The opposing idea to absolute territorial sovereignty proposed by the Harmon Doctrine is absolute territorial integrity, which stipulates all watercourse states enjoy equal rights to the utilization of a shared resource, and each watercourse state must respect the sovereignty and reciprocal rights of the other states (United Nations Fact Sheet, 2012).

Today state sovereignty remains an issue of debate in the context of international laws governing transboundary groundwater resources (UN Charter 1945; Eckstein and Sindico, 2014; McCaffrey, 2011; Dellapenna and Gupta, 2009). States have used this both arguments are reasons to opt in or out of international agreements. Both have been used in international texts over the past century, and have different implications. In general, downstream states favor the integrity principle, which prohibits upstream states from developing transboundary watercourses if it causes harm to downstream states. For the same reason, upstream states favor the sovereignty principle, which enables unlimited use of shared water resources. Figure 6 indicates the idea of sovereign control, subject to not causing significant harm, was included in the Stockholm, Mar del Plata and Rio Declarations but has been excluded in everything else until the ILC Draft Articles were passed in 2008 (Gupta and Conti 2016). With transboundary groundwater specifically the debate is over whether or not groundwater should be treated like other mineral resources like oil and gas, and therefore exclusively under sovereign control of the nation

(Sanchez et al, 2016). Others argue the inclusion of sovereignty “reverses decades of progress in international water law” (Conti and Gupta, 2016) because “the concept of sovereignty in water resources is not appropriate, water moves from one country to another without control” (Milanes-Murcia, 2013 p.3-44; McCaffery, 2011; McIntyre, 2011; Tanzi, 2011). If included in a potential treaty between the U.S. and Mexico, the principle of sovereignty could be used as an excuse not to cooperate, or it could be a necessary protection enabling further cooperation.

#### 1.5.4 Existing Groundwater Agreements Worldwide

This literature review found 8 aquifers with groundwater sharing arrangement (see Table 6). “Six transboundary aquifers have aquifer-specific legal mechanisms.” (Conti and Gupta 2016 p 851). In chronological order according the year the agreements were created, Table 6 displays the four transboundary aquifers have specific arrangements for allocation or data sharing (Sanchez et al., 2016).

The Genevese Aquifer shared by France and Switzerland is the only aquifer in the world with a joint management commission which regulates aquifer extraction and artificial recharge (Sanchez et al., 2016). In 2008 the “Convention on the Protection, Utilization, Recharge and Monitoring of Franco-Swiss Genevese Aquifer” was signed between the local cantons of France and Switzerland to replace the previous arrangement, which had been in effect since 1978 (Wohlwend, 2002). The agreement has a legally binding status and it is managed by experienced regional authorities for joint benefit (Genevois Convention, 2007). Each user group reports biannually, first estimating withdrawal rates, then reporting actual usage at the year’s end (Genevois Convention, 2007). Groundwater sustainability is overseen through the yearly management plan, which ensures “authorized extractions are matched by an equivalent volume of treated surface water recharge” (Wohlwend, 2002 p. 1). Costs are shared equally between the two states, although the recharge treatment plant is owned and operated by Switzerland (Wohlwend, 2002).

<b>Aquifer</b>	<b>Countries</b>	<b>Type</b>	<b>Title</b>	<b>Purpose</b>
Genevese	France, Switzerland	Legally binding	1978, updated 2008 Convention on the Franco-Swiss Genevese Aquifer	Jointly manage extraction and recharge of aquifer across country boundary. Official Title: Convention on the Protection, Utilization, Recharge and Monitoring of Franco-Swiss Genevese Aquifer
Abbotsford-Sumas	Washington State, USA, and British Columbia, CA	Informal	1992 Environmental Cooperation Agreement	Established an active Task Force composed of diverse stakeholder groups to coordinate efforts to protect the aquifer.
Northwestern Sahara Aquifer	Libya, Algeria & Tunisia	Informal, Verbal	1997 N/A	Rudimentary extraction controls
Hueco Bolson	El Paso, United States and Ciudad Juarez, Mexico	Informal MOU	1999 Memorandum of Understanding	Increase communications, cooperation, and implementation of transboundary projects of common interest. Signed between El Paso Water Utility Board (EPWU) and Junta Municipal Agua Saneamiento (JMAS)
Guarani	Brazil, Paraguay, Argentina, Uruguay	Informal Agreement	2010 Guarani Aquifer Agreement	Follows law principles of sovereignty, the equitable and reasonable use of water resources, the obligation not to cause harm, and the exchange of data and information. Potentially formalized if ratified by Brazil and Paraguay
Nubian Sandstone	Chad, Egypt, Libya & Sudan	Informal	2013 Regional Strategic Action Plan	Agreement creates a Joint Authority to manage the shared aquifer.
Iullemeden, Taoudeni/ Tanezrouft Aquifer System (ITAS)	Algeria, Benin, Burkina Faso, Mali, Mauritania, Niger, and Nigeria	Informal MOU	2014 Memorandum of Understanding (ITAS)	Establishment of a Consultation Mechanism for the Integrated Management of the Water Resources
Al-Sag/Al-Disi	Jordan and Saudi Arabia	Legally binding	2015 Management and Utilization of the Ground Waters in the Al-Sag /Al-Disi Layer	Establishes Joint Committee to manage, a protected area with extraction controls

Table 6. Groundwater Sharing Arrangements. Sources (Wohllwend, 2002; Stephan. (2013); Conti 2014; Sanchez et al., 2016; ITAS 2014; Sindico 2011; MOU 1999; Abbotsford-Sumas Aquifer International Task Force; Eckstein 2015; Genevois Convention, 2007).

## 1.6 Methodology Justification

### *Theoretical Framework*

#### Conti 2014: Eight Factors Enabling Transboundary Water Cooperation

1. Existing legal mechanisms
2. Existing regional institutions
3. Funding mechanisms
4. High institutional capacity
5. Previous water cooperation
6. Scientific research
7. Strong political will
8. 3<sup>rd</sup> party involvement

I will apply the Conti 2014 framework to assess the institutional capacity of the Paseo del Norte region (see box above). Conducting a global literature review, Conti 2014 compiled existing literature and governance frameworks on transboundary governance of aquifers to create a list of factors enabling cooperation over groundwater. These factors were created using the assumption made in Mirumachi's TWINS framework which refutes the popular dichotomy of framing either conflict or cooperation over water resources (Kirstin Conti, personal communication March 2017). Instead the TWINS framework proposes, though to varying degrees, both conflict and cooperation over water resources is constantly occurring (Zeitoun and Mirumachi, 2008).

I am using these factors identified by Conti 2014 to map the existing institutional water management structures. According to Willems, et al., 2003 p. 7 “more detailed capacity assessments could provide a clearer picture of the kind of future options a country can afford.” My methods of analysis directly support my ultimate objective- to identify options for more sustainable management of transboundary groundwater between the U.S. and Mexico.

### *Framework Modifications*

To apply the Conti framework on a deeper, scalar level using the Paseo del Norte case study, I have slightly modified it. First, the previously identified seven factors [Legal mechanisms, governmental institutions, third party involvement, previous water cooperation, scientific research, funding mechanisms, political will] contribute to the eighth factor, the overall assessment of institutional capacity.

Second, I added levels of “no cooperation” and “partial cooperation” to the ranking scale to enable a more nuanced analysis of the current situation. In addition, there is now a five-point scale which gives the overall assessment a more neutral option. Third, I changed “existing regional capacity” category to “governmental institutions” because this category was overlapping with the “high institutional capacity” and “third party involvement.” Fourth, this entire assessment is specific to relationships around groundwater resources. However, the “previous water cooperation” and “political will” sections include dynamics surrounding all water resources.

### *Expected Outcome*

Because the surface and groundwater hydrologic systems are connected, I hypothesized adapting the surface water treaties would be the most popular and feasible option to enhance sustainable use of groundwater. This postulation is based simply from the aforementioned fact there are hundreds of treaties worldwide which allocate surface water and one which allocates groundwater (See section 1.5.4). As a result, I created a map to spatially visualize where treaties could be amended to include groundwater. In the Paseo del Norte study area there are two treaties though only the 1944 Treaty has the ability to be amended. During my interviews I expected to find stakeholders in the region would be amenable to altering the 1944 Treaty. In the discussion section, the results suggest otherwise. First, the next section outlines the methods used to conduct the analysis.

## CHAPTER II. METHODS

### Research Questions:

1. What are options to sustainably manage transboundary groundwater?
2. Institutions are currently best equipped to jointly manage groundwater across which scales?
3. How can legal, economic and scientific options contribute to more sustainable management of transboundary groundwater across scales [local, state, national, and international]?

There are two main components of this research, the global analysis (Part I.) and the case study (Part II).

### *Part I. Global Spatial Analysis*

The purpose of the global analysis was twofold. First, at the request of IGRAC and UNESCO-IHP a map was created to visualize the SDG indicator 6.5.2. Using ArcMap Geographic Information Systems (GIS), I created a global map of the transboundary aquifers overlaid by the transboundary river basins that have water treaties. This map highlights areas that have institutional potential to include groundwater because a surface water treaty exists. Second, based on the findings from the first map, this map was expanded upon and used as the foundation for my analysis of institutional potential at the international scale. A specific case study in the Paseo del Norte region is examined for a more comprehensive institutional analysis at the international, national, and regional scales.

### *Part II. Case Study*

I will apply Conti's 2014 "Factors Enabling Transboundary Aquifer Cooperation" to assess the institutional capacity of the Paseo del Norte region. To accomplish this assessment, I conducted primary research through interviews in the Paseo del Norte region and secondary research with an extensive literature review. Personal, skype, and phone interviews were conducted in order to gain a better understanding of the relationships between the differing water management institutions in the basin. The literature review for the case study was conducted using Oregon State's and UNESCO-IHE's library databases. Keywords used for the literature review included: transboundary, aquifers, groundwater, governance, international treaties and in Spanish- acuíferos, aguas subterráneas, transfronterizo, gestión de agua en ciudad juarez, cuencas y Rio Bravo. Academic articles were complemented with a broad internet search of scientific and diplomatic federal reports, newspaper articles, powerpoint presentations, Supreme Court cases, hydrogeological consultant reports, USGS reports, and binational publications. Information about Mexico was mainly found through searches using Spanish keywords. I found there are

many documents describing local water management that have not been translated to English including the location of the wells (pozos) and the construction of the newest San Jeronimo well field.

## 2.1 Global Analysis

I used ArcMap Geographical Information System (GIS) software to visualize the spatial distribution of transboundary aquifers in relation to transboundary river basins. This enabled a comprehensive analysis of spatial patterns, trends, and gaps in groundwater governance frameworks at multiple scales (international, domestic, regional). Additional tools are necessary to augment the information communicated by the maps. The tables in the previous section address this by further explaining the current groundwater agreements (Table 6) and international water law principles applicable to groundwater governance (Figure 6). The three resulting maps effectively serve as a tool to produce, display, and manage data and will ultimately contribute to the overall goal of assessing the water management institutions across scales to find options for sustainable management of transboundary aquifers.

Data gathered for the GIS ArcMap analysis consisted of three primary shapefiles, which were manipulated and edited along the process (See Table 7).

Organization	Shapefile	Permission
OSU TFDD Oregon State Transboundary Freshwater Dispute Database	Global Transboundary River Basins	Open source
IGRAC International Groundwater Resource Assessment Center	Global Transboundary Aquifers	Private, permission granted
FAO Food Agriculture Organization of the United Nations	Global Political Countries	Open source

Table 7. Sources of primary GIS data used in the analysis



Two main objectives were created for this mapping project.

### **Step 1.**

*Goal:* Find the proportion of transboundary basin area with an operational arrangement for water cooperation.

*Purpose:* This directly addresses SDG indicator 6.5.2 “Proportion of transboundary basin area with operational arrangement for water cooperation.”

*Assumptions:* I used the area of transboundary basins covered by treaties to serve as "operational arrangement for water cooperation." I realize this is not by any means the only way to define operational arrangement. For example, research by McCracken (2017) presents other methods to define operational arrangement.

### **Step 2.**

*Goal:* Find the proportion of transboundary river basins with treaties that overly aquifers.

*Purpose:* Create a global map that displays river basins covered by surface water treaties.

*Assumptions:* The assumption made is the river basins that are covered by treaties have a greater institutional capacity to make a potential agreement on groundwater. A treaty is an indicator of previous cooperation over water resources. Therefore river basins with treaties over surface water have a greater potential to either amend the treaty to include groundwater or create a new treaty.

#### 2.1.1 GIS ArcMap Methods

1. I imported the three above mentioned shapefiles into ArcMap 10.0 to visualize the data spatially.
2. I reprojected all of the shapefiles into “World Cylindrical Equal Area” projection in order to maintain the integrity of the area measurement for each country.
3. To create an additional shapefile of the river basins that only included treaties, I exported the shapefiles’ attribute tables into Microsoft Excel and coded the interviews using the binary “0” for no treaty and “1” for one of more treaties.
4. I created a new shapefile of the river basins with a treaty by importing the excel spreadsheet into the master ArcMap document.
5. Using the "Intersect" tool, I created another new shapefile which displayed the area where aquifers and river basins overlapped.

6. The Geometry Property "AREA\_GEODESIC" was added to the attribute table in order to derive the most accurate area calculation. (For this step I validated the methods with a professional from ESRI, the creator of ArcMap).
7. I reprojected the whole map into Psuedo Mercator using QGIS and adjusted the colors to make the map more visually appealing. Combinations of graduated colors and hashes were used to show relationships between the data.
8. The attribute tables were again exported to excel, this time for a quantitative analysis.
9. Simple division of overall areas was used to calculate final numbers (as area in kilometers squared).

## **2.2 Case Study**

### 2.2.1 Interviews

Primary research was conducted through a snowball sampling technique of interviews in the study area. Snowball sampling is defined as “A technique for finding research subjects where one subject gives the researcher the name of another subject, who in turn provides the name of a third, and so on” (Vogt, 1999). This method was chosen for two reasons- to access a specific group of water managers in the study area and to better understand the relationships dynamics between stakeholders. I requested and was granted an oversight determination exemption through the Institutional Review Board (IRB) because the context of the interview stayed within the limits of professionals representing their respective agencies. Personal interviews accounted for 12 of the 28 total interviews. The remaining interviews were conducted via Skype. A comprehensive list of the people interviewed can be found in Appendix D and Table 7 displays a breakdown of interviewee diversity. The interviews took place between Albuquerque, NM and El Paso, TX. There were no personal interviews conducted in Ciudad Juarez due to logistical concerns of visiting Mexico. The participants were carefully selected based on their role in water management in the Paseo del Norte region. The goal was to talk to managers on all scales, and ultimately a wide range of federal, state, and local managers were successfully interviewed. The interviews were set up using the semi-structured approach with the average length of the interview 45 minutes. The advantage of the semi-structured approach is the open ended nature of the predetermined questions inhibits the participant to move beyond the questionnaire (DiCicco-Bloom and Crabtree, 2006). The questions were centered around cooperation and conflict over groundwater resources in the basin. It was my underlying goal to gain a broader understanding the institutional picture. Namely, who each of the water managers are, on

what scale, who do they communicate with, cooperate with, and which laws are they restricted. The personal interviews contributed directly to this goal.

The interview questions consisted of the following 6 questions:

1. How has groundwater acted as a catalyst for cooperation in the lower Rio Grande Basin?
2. What is the biggest point of contention over groundwater? I.e. Rights, sustainability, pumping, regulation?
3. Ideally, what would be the most equitable/fair way to manage groundwater resources between southern New Mexico, Texas and Mexico?
4. How do you foresee this happening? I.e. Future litigation, local agreements, MOU
5. What is your preferred method of dispute resolution? I.e. litigation, mediation, meetings, joint creation of agreements.
6. Which other agencies do you communicate with to solve water issues in the basin? How often?

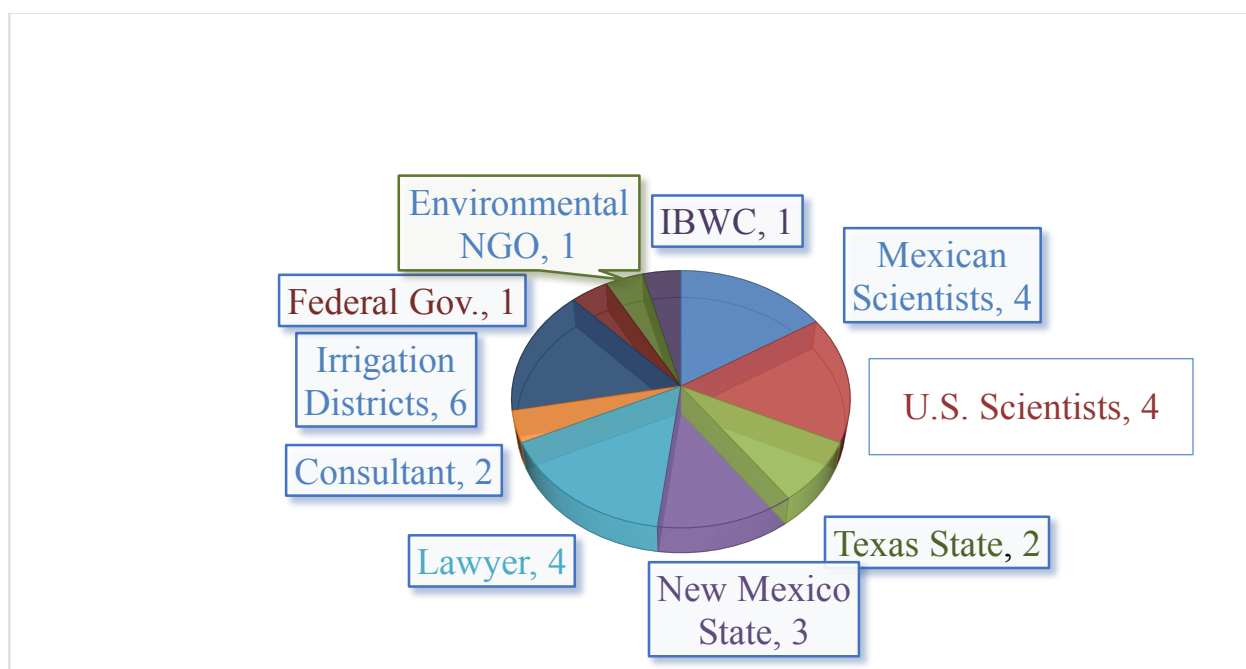


Figure 7. Categories of Interviewees, number represents number of people interviewed

### 2.2.2 Assessment of Institutional Potential for Cooperation

Conti 2014 framework was adapted to enable a deeper analysis of the institutions across scales. Table 9 displays the matrix I created to visualize each of the scales for Mexico, the United States, and Joint governance institutions.

Scale	1. Legal Mechanisms		
	MX	U.S.	Joint
Federal			
State			
Local			

Table 9. Example of Assessment of Transboundary Cooperation (adapted from Conti 2014)

The cooperation ranking scale is described below:

0. *No cooperation*- no cooperation over transboundary groundwater
1. *Partial cooperation*- states either communicate over groundwater quality *or* quantity
2. *Low cooperation*- states previously engaged about the transboundary aquifer but those activities are dormant or cooperative activities are informal, some might exist in name only
3. *Moderate cooperation*- there is ongoing cooperation. It is occurring outside of a formal institution, a formal water management institution has just begun, or formal cooperation is sporadic.
4. *High cooperation*- there is current frequent cooperation in the context of a formal institution or formal project.

The above box describes the scale used to rank the level of cooperation. The specific methods for this research were first to rank (U.S., Mexico, Joint) across 3 scales, (federal, state, local) for each of the 7 factors. The ranking is based strictly from the level of cooperation then overall institutional capacity was evaluated based on the average of the other seven factors. These factors are not weighted because weighting according to what I perceive as more important would create an additional layer of subjectivity.

To clarify, I am not assessing the effectiveness of these 7 factors because this would entail determining to what degree they accomplish or implement tasks. This could be done with a future study using the IAD framework and significantly more time. Instead I am assessing to which degree the institutions play a cooperative role in ground water management in the basin. By mapping the existing institutional structures across multiple scales, I can better understand how to bridge the gap in the fundamental differences between U.S./Mexican governmental agencies and regulatory laws. The result will point to gaps in institutional capacity and places to center resources to develop cooperative efforts.

## CHAPTER III. RESULTS

### 3.1 Spatial Analysis, *Global Scale*

#### Step 1.

*Goal:* Find the proportion of transboundary basin area with an operational arrangement for water cooperation.

*Purpose:* This directly addresses SDG indicator 6.5.2 “Proportion of transboundary basin area with operational arrangement for water cooperation.”

*Assumptions:* I used the area of transboundary basins covered by treaties to serve as "operational arrangement for water cooperation." I realize this is not by any means the only way to define operational arrangement.

*Results:* The area of transboundary river basins covered by a treaty divided by the total area of transboundary river basins= 79% (Corresponding visual image, Figure 8).

$$\frac{\text{Area TB River Basins with Treaty}}{\text{Total area of TB River basins}} = \frac{50,339,600 \text{ km}^2}{63,279,500 \text{ km}^2} = 79\%$$

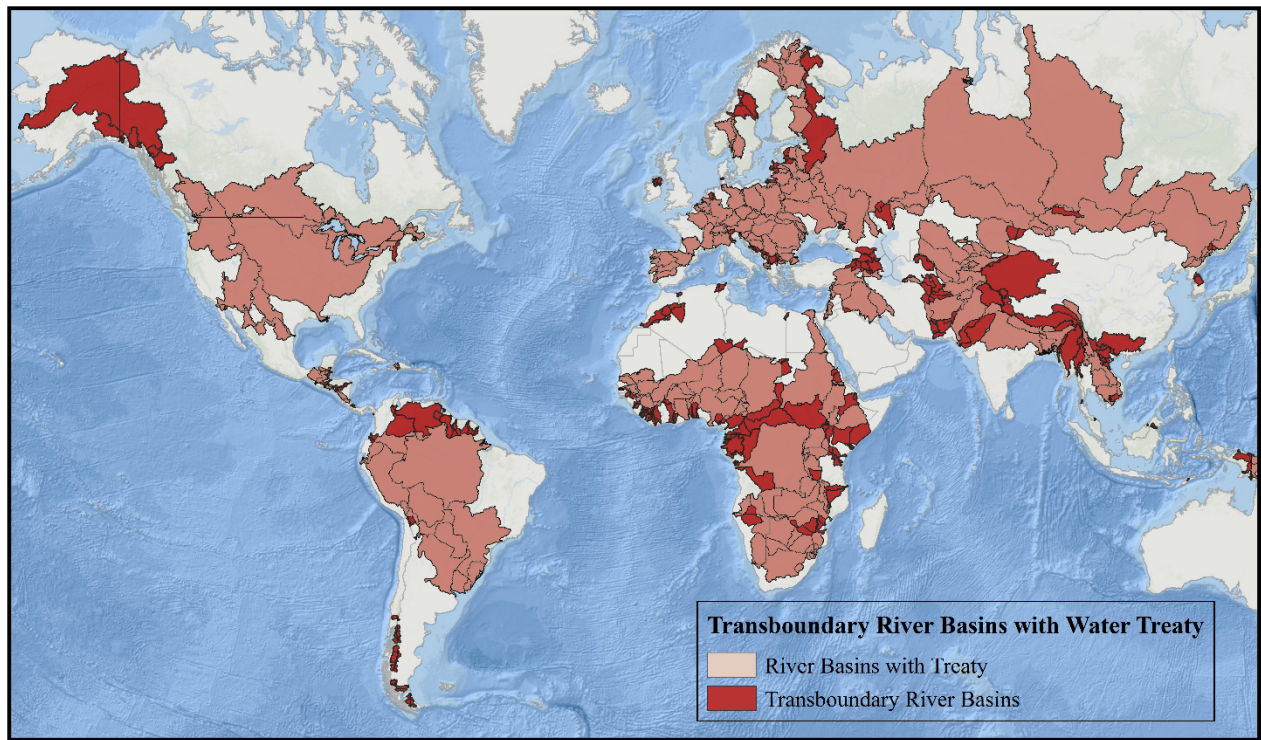


Figure 8. Global Transboundary River Basins with a Treaty



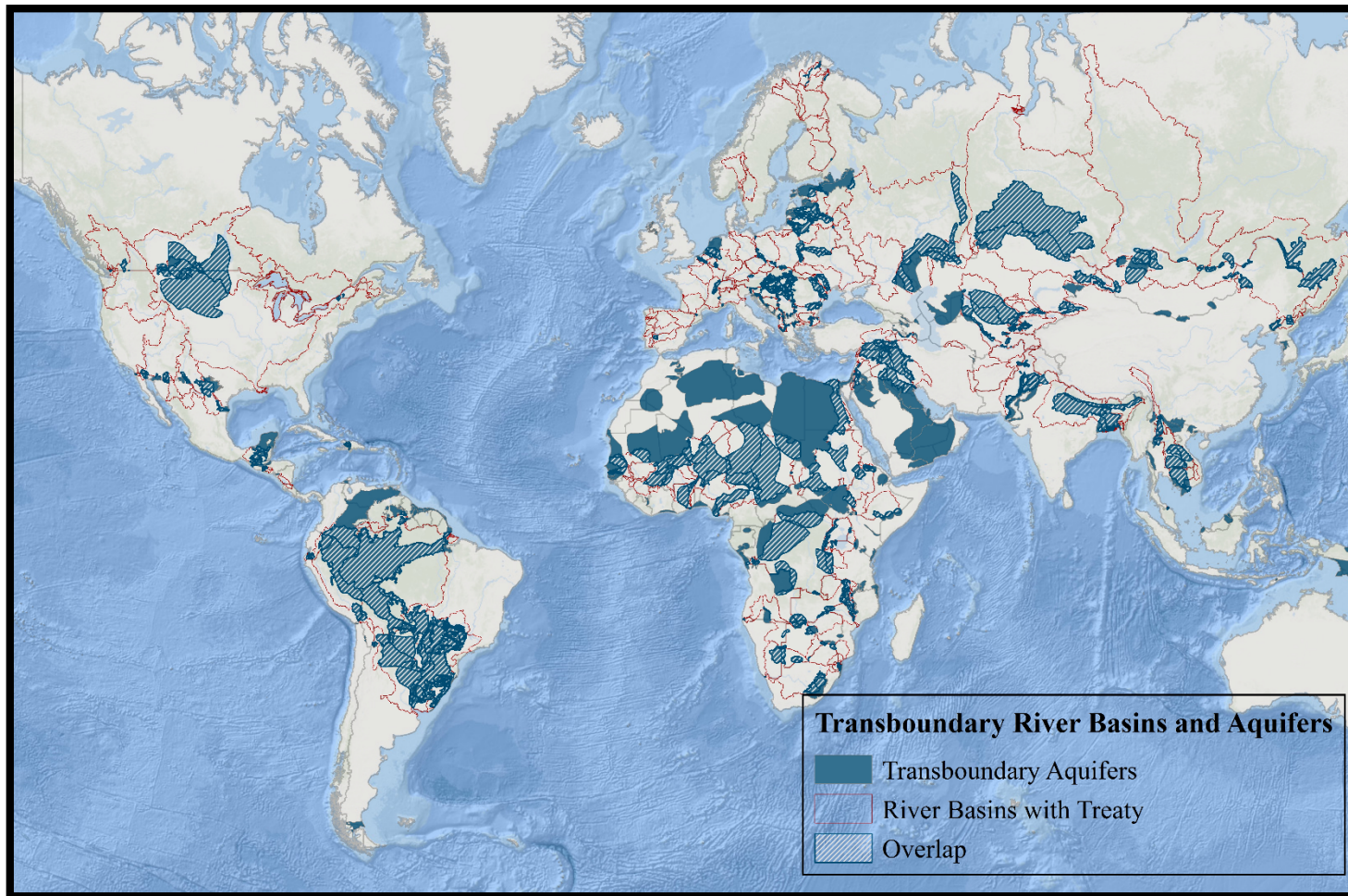


Figure 9. Global Transboundary River Basin with Treaty Overlap with Transboundary Aquifer

## Step 2.

*Goal:* Find the proportion of transboundary river basins with treaties that overly aquifers.

*Purpose:* Create a global map that displays river basins covered by treaties.

*Assumptions:* The assumption made here is the river basins that are covered by treaties have a greater institutional capacity to make a potential agreement on groundwater. A treaty is an indicator of previous cooperation over water resources. Therefore river basins with treaties over surface water have a greater potential to either amend the treaty to include groundwater or create a new treaty.

*Results:* Area of overlap between transboundary aquifers and river basins divided by area of river basins covered by a treaty= 34% (Corresponding visual image, Figure 9). Figure 10 zooms into the study area using the map from Figure 9.

$$\frac{\text{Overlap: TB River Basins with Treaty} + \text{TB Aquifers}}{\text{Area TB River Basins with Treaty}} = \frac{17,281,300 \text{ km}^2}{50,339,600 \text{ km}^2} = \mathbf{34\%}$$

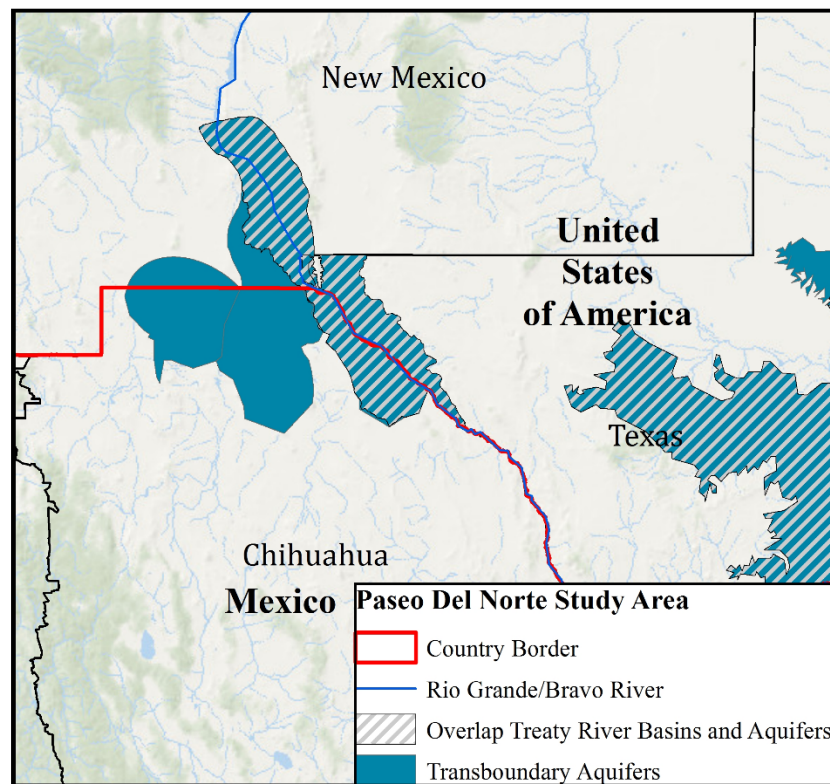


Figure 10. Rio Grande/Bravo Basin Study Area with applied Transboundary Aquifer Map



### 3.2 Case Study, *International, State, Regional Analysis*

Research Questions:

1. What are options to sustainably manage transboundary groundwater?
2. Institutions are currently best equipped to jointly manage groundwater across which scales?
3. How can legal, economic and scientific options contribute to more sustainable management of transboundary groundwater across scales [local, state, national, and international]?

This next section addresses the following research questions by applying Conti 2014 analytical framework. Specifically, the following 7 factors [Legal mechanisms, Governmental Institutions, Third Party Involvement, Previous Water Cooperation, Scientific Research, Funding Mechanisms, Political Will] are compiled to create an overall analysis of the current institutional capacity to manage groundwater.

#### 3.2.1 Legal Mechanisms

According to Conti 2014, legal mechanisms are defined as: “Laws that place binding obligations on aquifer states; binding legal agreements with requirements for monitoring, modeling or managing an aquifer; legal agreements for surface water bodies which include hydrologically connected groundwater in their scope; supranational regulatory requirements for groundwater. Non-binding mechanisms are also included as factors so long as they specifically address management of groundwater resources between the aquifer states and originate from an international body with legal authority or government officials” (p.22). This section identifies the existing legal mechanisms across the scales. While Conti is referring to strictly the joint legal mechanisms, I also included the existing legal mechanisms that govern groundwater in each state. The purpose is to include a deeper understanding of the legal structure in place to identify places where legal agreements could be made.

#### *Joint Legal Mechanisms*

There is a long history of legally binding and non-binding agreements in the Rio Grande River Basin between the U.S. and Mexico (see Table 8). The IBWC is the governing body for the international treaties while the Rio Grande Compact Commission is the governing body for the interstate Compact. The following section briefly discusses the capacity of each country to make an international agreement at the federal level.

Year	Agreement	Parties	Significance
1848	Treaty of Guadalupe Hidalgo	United States and Mexico	Settled the Mexican-American war, redrew Mexico's northern border, created states of New Mexico, Arizona, Nevada, Utah, Wyoming.
1905	Rio Grande Project Act	United States	Approved by U.S. Congress, water for irrigation of 88,000 acres of land are allotted to southern New Mexico and 67,000 acres to western Texas. (Littlefield 1999) Those proportions are roughly equivalent to 57% for EBID in New Mexico and 43% for EPCWID in Texas (Amicus, 2013).
1906	Convention on Equitable Distribution of the Waters of the Rio Grande	United States and Mexico	Delivery of 60,000 acre-feet/year (74 million cubic meters) of water U.S. to Mexico for surface water above Fort Quitman, TX. (Amicus, 2013)
1939	Rio Grande Compact (hereby "Compact")	Colorado, New Mexico, Texas	Equitably apportions the waters of the Rio Grande above Fort Quitman, Texas in the United States. Sets Colorado's delivery point as the New Mexico state line. New Mexico's delivery point to Texas is Elephant Butte Reservoir. The delivery amount varies proportionally from year to year depending on surface water available.
1944	Water Treaty "Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande"	United States and Mexico	The treaty allocates water below Fort Quitman, TX. "Mexico has rights to two-thirds of the flows of six Mexican Rio Grande tributaries. The one-third delivered to the United States must average at least 350,000 AF per year, measured in five-year cycles (Carter et al., 2015)"
1963	The Chazimal Convention	United States and Mexico	Resolved 100 year long border dispute due to change in the course of the Rio Grande. The U.S. ceded the majority of the land back to Mexico and a channel was cemented between El Paso and Ciudad Juarez.
1983	La Paz Agreement	United States and Mexico	To protect the environment along the border by preventing, reducing and eliminating sources of pollution (La Paz Agreement, 1983).

Table 8. Timeline of Treaties in Rio Grande Basin (Grimsal, 2017; Milanes-Murcia, 2013)

### *U.S. Treaty Making Process*

In the United States, there are two ways an international agreement can be made- by treaty or an executive agreement (Garcia, 2015). There are three types of executive agreements, each with different requirements (See box below).

1. **Congressional Executive Agreements**- both houses of Congress need to authorize
2. **Executive Agreements following an earlier treaty**- the Senate authorizes amendments. Often, implementing legislation is necessary to enforce the treaty.
3. **Sole Executive Agreements**- the President has Constitutional authority, which does not require authorization by Congress.

Box adapted from (Garcia, 2015 and Jacobson, 2015).

In a 2015 press release from the White House, Joe Biden stated,

"Around the world, America's influence depends on its ability to honor its commitments. Some of these are made in international agreements approved by Congress. However, the vast majority of our international commitments take effect without congressional approval." (Biden, 2015).

Approving an international treaty (not executive agreement) "requires  $\frac{2}{3}$  majority vote in the Senate" (Garcia, 2015), which is growing increasingly harder to achieve. Jeffrey S. Peake and Glen Krutz tracked the number of executive agreements steadily rising in lieu of international treaties (Jacobson, 2015). Between 1789 and 1839, a mere 31 % of agreements were executive orders rather than treaties, from 1889 to 1939, 63.6 % of agreements were executive orders, and from 1939 to 1989, 94.3 % of international agreements in the United States were in the form of executive orders. (Jacobson, 2015). According to this trend, a potential new treaty would need approval by a sole executive order from the President of the U.S.

### *Mexican Treaty Making Process*

In order for a treaty to be adopted by Mexico, the Mexican Constitution requires the treaty to be signed by the President of Mexico, Senate approval, approval from one of the two houses in the federal legislature, and published in the Federal Official Gazette (Weiss, 1998).

## *Binational Treaties*

### **1906 Convention**

The 1906 Convention was signed between the United States and Mexico allocating the delivery of 60,000 acre-feet/year of Rio Grande/Bravo surface water from the U.S. to Mexico for above Fort Quitman, TX (Amicus, 2013). The delivery point is the International Dam located between El Paso and Ciudad Juarez (see Figure 11). The International Diversion Dam is owned and operated by the IBWC-CILA. In years of extreme drought, the United States can proportionally reduce the delivery amount and is not required to make up for the reduction at a later time (Convention, 1906). From 1939 to 2013, deliveries to Mexico were reduced in roughly 30% of the years; between 2012- 2015 Mexico has not received more than 60% of their full allotment under the 1906 Convention due to the “extraordinary drought” (Carter et al., 2015). The drought is blamed for junior water rights holders in New Mexico receiving as low as 4% of allotment over the past 10 years (Carter et al., 2015). Unlike the 1944 Treaty, this Convention does not have a mechanism built in to make amendments (Convention, 1906).

### **1944 Treaty**

The 1944 Treaty allocates the surface waters of the Rio Grande below Fort Quitman, Texas. Mexico has the rights to  $\frac{2}{3}$  of the flows from six Mexican tributaries, and must deliver  $\frac{1}{3}$  to the United States (Carter et al., 2015). The deliveries to the United States are measured in 5 year cycles and must have an average of at least 350,000 Acre Feet (AF) per year (Treaty, 1944). Unlike the 1906 Convention, if a water debt is accrued, Mexico is required to pay back the debt in the next cycle. Mexico has consistently been falling behind on the allocation to the United States, which has angered the U.S. stakeholders (Carter et al., 2015). In 2015 an estimated 100,000 AF of the water delivered from Mexico was from sources not explicitly accounted for in the 1944 Water Treaty (Carter et al., 2015). Dispute resolution and amendments occur through the “minute” process. This process allows the IBWC to amend the 1944 Treaty using legally enforceable means (1944 Treaty, art. 25). Minute 242 is the only minute that mentions groundwater (See section 1.5.3 Precautionary Principle).

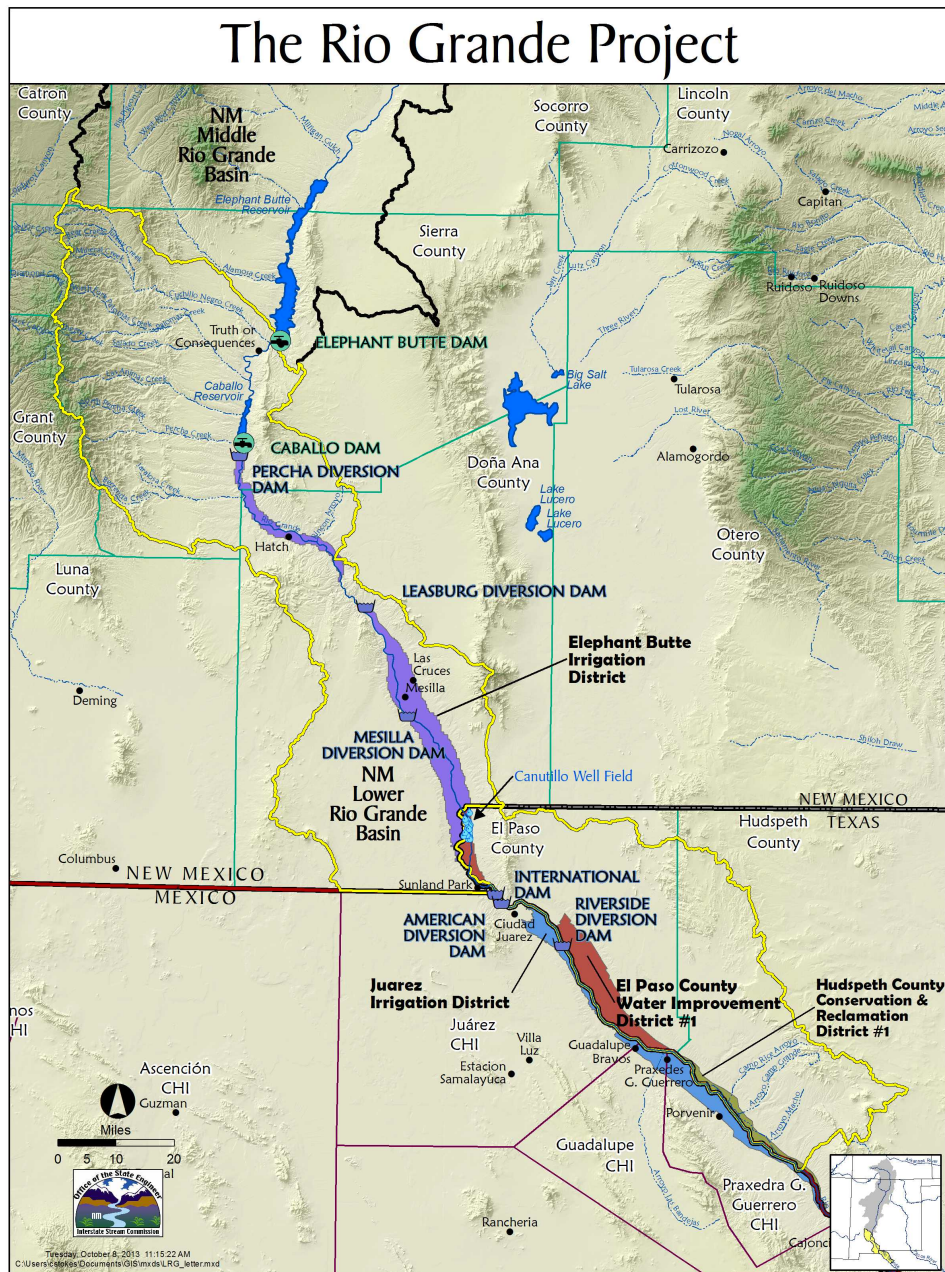


Figure 11. Location of Diversion Dams and Canals on the Upper Rio Grande/Bravo River. (OSE, 2015)

### *Legally Non-binding Agreements*

#### **MOU Federal Level, EPA and CONAGUA**

In 2000 the U.S.EPA and Mexico's CONAGUA signed "Memorandum of Understanding Concerning the Joint Grant Contributions for Drinking Water Supply and Wastewater Infrastructure Projects for Communities in the United States – Mexico Border Area." Under the NAFTA (North American Free Trade Agreement) environmental framework, this marked a concerted effort from the U.S. and Mexican governments to jointly address these transboundary water quality problems.

#### **MOU Local Level, Ciudad Juarez and El Paso**

The 1999 Memorandum of Understanding between City of Juárez, Mexico Utilities and the El Paso Water Utilities Public Services Board of the City of El Paso, Texas (MOU,1999). Although legally non-binding, the goal was to "identify the mechanisms between the parties to increase communications, cooperation, and implementation of transboundary projects of common interest." (Eckstein, 2011 p. 284). Notably, the arrangement includes data and information sharing, cooperation for the management, use and protection of transboundary aquifers (Eckstein, 2011)

#### **MOU local level El Paso #1 and El Paso Water Utilities**

In 1962 the city of El Paso water utility entered into a 75-year agreement with El Paso Irrigation district #1 to lease irrigation water for domestic supply (El Paso Water Utility, 2007). The document recognizes the need for conjunctive management of water resources (Hamlyn et al., 2002).

### *Interstate Treaties, United States*

There is no mention of groundwater in the interstate Rio Grande Compact. However surface water management is important to understand given the potential for existing surface water agreements to be amended to include groundwater. This section explains the institutional complexity surrounding the surface water allocation of the Rio Grande river water in the United States.

When the Elephant Butte reservoir was built by the newly created Bureau of Reclamation in 1916, Congress determined the water from Elephant Butte Reservoir be used for "irrigation purposes only." (Schmandt, 2002). If water is used for any other purpose besides irrigation, it is subject to the 1920 Miscellaneous Act, in which the irrigation district must approve another use. This has resulted in a situation for the past century in which the irrigation districts (EBID and EP#1) control all of the surface

water between Elephant Butte Reservoir, NM and Fort Quitman, TX. Because of the stipulation, it has been difficult to secure surface water for environmental flows and municipal use.

<b>Year</b>	<b>Law</b>	<b>Purpose</b>
1907	New Mexico Water Code	Designates the New Mexico State Engineer responsible for administering the existing water uses, to preserving the aquifers, and meeting New Mexico's Compact obligations (Water matters, 24-2)
1920	Sale of Project Water for Miscellaneous Purposes Act	This enabled a conversion from irrigation water to be used for other purposes. The irrigation districts must approve any requests.
1956	Middle Rio Grande Groundwater Basin declared	State Engineer Reynolds declared all groundwater pumping requires a permit and a forfeiting of equivalent surface rights.
1979	Transfer of O&M in the Rio Grande Project	There was a transfer from the BoR to EBID and EP#1 took over Operation and Management of Rio Grande Project (Cortez, 2008).
1980	The Lower Rio Grande Basin Groundwater Basin declared.	Steve Reynolds, New Mexico's State Engineer at the time mandated a permit is required and a forfeit of equivalent surface water rights before pumping groundwater (BoR, 2013).
1999	New Mexico Mesilla Valley Administrative Area Guidelines	Established by OSE to formally recognize "groundwater withdrawals will ultimately result in depletions of surface-water sources"(BoR, 2013 p.53). The goal was to protect the existing water rights from the effects of groundwater pumping.
2004	New Mexico Groundwater Metering Order	OSE passed the Lower Rio Grande Water Master District to establish an area and then the Metering Order which stated all wells must be metered within the district except for wells that serve one household (BoR, 2013).

Table 9. Timeline of New Mexico Ground Water Policy

### **1905 Rio Grande Project Act**

In 1902 Congress passed the Reclamation Act, which soon after authorized the Rio Grande Project Act (Cortez, 2008). The Rio Grande Project build the Elephant Butte Reservoir in 1916, with a capacity of 2,056,010 AF of water can supplies irrigation water for 728 km<sup>2</sup> of U.S. land and 100 km<sup>2</sup> Mexican land

(178,000 total acres of land) and electric power for surrounding communities (Wheat, 2015). It is operated by the Bureau of Reclamation. Today the Rio Grande Project provides water for irrigation of approximately 178,000 acres in New Mexico and Texas (Carter et al., 2015). The full allocation for Project irrigated land is 3.0412 acre-ft per acre/year (Cortez, 2008). The Project currently has grown to encompass the Elephant Butte and Caballo storage dams, four diversion dams, hundreds of kilometers of canals, laterals, open drainage ditches, and a hydroelectric plant (Cortez, 2008).

### **1938 Rio Grande Compact**

The states of Colorado, New Mexico and Texas signed the Compact March 18, 1938 (hereby referred to as “Compact.” The U.S. Congress ratified Compact on May 31, 1939 and it entered into force (BoR, Rio Grande Project Presentation). The Compact allocates water between the three states, taking into account the 60,000 AF/year for Mexico under the 1906 Convention (Rio Grande Compact, 1938). The delivery point for Colorado is at the Colorado/New Mexico state line. The delivery point for New Mexico to Texas is at the Elephant Butte Reservoir, in southern New Mexico. The Compact operates on a credit and debit system, which agreed upon margins for each credit and debit (Wheat, 2015). If the Elephant Butte Reservoir spills over, all credits and debits accrued by the states are erased. The original compact agreement allocated 57% of the reservoir water to EBID in New Mexico and 43% to EPCWID (EP#1) in Texas. However, the 2008 Operating Agreement changed the percentage allocated (BoR Operating Agreement, 2008).

The Compact relies on equitable apportionment of Rio Grande water between the three states. The outcome from the 1938 case *Hinderlider v. La Plata River & Cherry Creek Ditch Co.*, 304 U.S. 92 determined the equitable apportionment “is binding upon the citizens of each State and all water claimants, *even where the State had granted the water rights before it entered into the compact.*” (Grimsal Special Master’s report p. 106 emphasis added). In essence, it has held up in court that water committed by a compact agreement (between states) takes priority over federal and state laws.

### ***Current Litigation***

The outcome of the ongoing Supreme Court Case Texas v. New Mexico and Colorado 2013 could change how surface water is allocated between New Mexico and Texas and how groundwater is accounted for. Although the following section describes litigation, the opposite of cooperation, it could be a driver for cooperative effort behind the scenes. According to interview sources, there is a settlement negotiation



team currently working to come up with a solution before the case is heard before the Supreme Court. The series of events leading to TCEQ filing the 2013 lawsuit is critical to understanding stakeholder dynamics in the basin.

### *Summary of Events Leading to the 2013 Supreme Court Case (Texas v. New Mexico)*

The 2008 Operating Agreement changed how the Rio Grande Compact water was allocated. Specifically, the agreement reduced New Mexico's allotment taking into account pumping from southern New Mexico. This manifested as a shift from the 57% EBID, 43% EP#1 to non-fixed percentages (BoR Operating Agreement, 2008). Specifically, EP#1 is allocated 43% of what would have been available under the 1951-1978 baseline conditions, and EBID the remainder of what is actually available under current conditions (Dr. Phillip King, personal communication, January 23, 2017). This agreement settled two ongoing lawsuits between parties and was considered a major cooperative achievement which involved complex water budget calculations and years to finalize (Gary Esslinger and Dr. Phillip King, personal communication, January 23, 2017). The parties to this Operating Agreement were the EBID, EP#1 and the Bureau of Reclamation. The state departments for Texas and New Mexico were either purposefully excluded from negotiation of the agreement, or knowingly did not choose to participate. In response to this Operating Agreement, in 2012 the New Mexico Attorney General Gary King filed a lawsuit *NM v. United States, EBID, EPWCID#1* in the New Mexico federal district court (Water Matters, 24-2). Reasons for the lawsuit were cited as violation of NEPA standards, and unlawful release of Rio Grande Compact credit water from Elephant Butte Reservoir (Water Matters, 24-2). As a result of this lawsuit, the state of Texas (TCEQ) responded by filing the 2013 lawsuit in the Supreme Court.

### *Supreme Court Case Texas v. New Mexico and Colorado 2013*

Texas claims New Mexico is violating their share of equitable apportionment allocated by the Rio Grande Compact and the Rio Grande Project Act by diverting surface and groundwater in the 100 miles below Elephant Butte Reservoir and the Texas state line (Grimsal, 2017). The point of delivery outlined in the Compact from New Mexico to Texas is above the Elephant Butte Reservoir at the San Marcial gauge NM, 100 miles from the Texas border. Texas states once the water is released from the Elephant Butte Reservoir, it becomes Texas water, and New Mexicans do not have a right to divert this water. In 2014 the Supreme Court has appointed a special master

Gregory Grimsal to the case to gather evidence. The Special Master's report was released February 7th, 2017. In this report Grimsal recommends to the Supreme Court: denying New Mexico's motion to dismiss the case, and denying the two irrigation district's request to intervene. If the Supreme Court takes the recommendations of the special master, it is likely they will see the case. The Special Master's report appears to favor Texas. "The equitable apportionment achieved by the 1938 Compact commits the water New Mexico delivers to Elephant Butte Reservoir to the Rio Grande Project; that water is not subject to appropriation or distribution under New Mexico state law" (Grimsal, 2017 p. 211).

*"They [Texas] found 3.3 million acre feet of water that they were shorted. At \$300 an acre foot, a fair price, that's what it goes for in El Paso right now, you are looking at 1 billion dollars in damages."*  
(Dr. Phillip King, EBID consultant, personal communication, January 23, 2017)

### *New Mexico Lower Rio Grande water rights Adjudication*

Relevant to the case study is the ongoing adjudication of water rights in the New Mexico Lower Rio Grande basin. The adjudications are occurring under the 1996 lawsuit *New Mexico v. EBID* within the New Mexican state court. The goal of this adjudication is to formally settle the water rights for over 18,000 claimants and determine the groundwater rights of those in the EBID and others in southern New Mexico (Water Matters, 24-2).

## **United States Water Law**

### **Federal**

The water policy today is a reflection of the evolution of complex balance between federal and state power since the inception of the United States. Today the federal government is largely responsible for water quality while the state governments are responsible for water quantity allocation. The Clean Water Act and the Safe Drinking Water Act are two examples of federal action to establish minimum water quality standards (Eckstein, 2011). There is not, on a federal level, regulation of groundwater quantity. The Safe Drinking Water Act does regulate groundwater quality. Additionally, the government operates water supply and storage systems for public and private use (Reimer, 2012). Individual states can establish more rigorous standards if necessary, but they must comply at a minimum to the standards outlined by the federal government. States and local government maintain ultimate control over these water resource, which is evident by state specific water law and allocation of water rights. The random

smattering of disparate state laws that govern groundwater coupled with the absence of a national frameworks make it impossible for the U.S. federal government to govern groundwater as a unified whole (Mumme, 2000 and Eckstein, 2011).

### State

In the Western U.S. Texas and New Mexico notwithstanding, water rights are considered property right, and therefore are regulated by state law. State water laws have evolved unilaterally, to the point they are sometimes conflicting with neighboring state water laws. Specific to the study area, groundwater rights in Texas under the rule of capture doctrine are considered attached to the land rights and not state property (Eckstein 2011). Groundwater rights in New Mexico under the prior appropriation system are owned by the state and allocated by State Engineer (Wheat 2015). The respective state legal systems are described briefly below.

#### **New Mexico State Water Law**

##### *Regimes: Prior Appropriation*

Water law in New Mexico is based from the prior appropriation system which states in times of drought, the senior user will receive full allocation of water before the junior user (Wheat, 2015). A water right in New Mexico has five components: quantity, purpose of use, owner, place of use, and point of diversion (BLM, 2001). Unlike Texas, which treats groundwater and surface water separately, since the 1962 court decision *City of Albuquerque v. Reynolds*, New Mexico has conjunctively managed surface and groundwater (Wheat, 2015).

New Mexico State Constitution defines *water* as:

“the water of underground streams, channels, artesian basins, reservoirs or lakes, having reasonably ascertainable boundaries, is declared to belong to the public and is subject to appropriation for beneficial use.” (New Mexico State Constitution, 1911)

There is an emphasis on beneficial use in New Mexico. According to the constitution beneficial use is “the basis, the measure and the limit of the right to the use of water.” (N.M. CONST. Art. XVI, § 2 and 3). There is not an official list of “beneficial use” but the State Engineer has declared beneficial use on an individual basis in the past for: agricultural, commercial, domestic, industrial, recreational uses, state conservation goals, and stock-watering (BLM, 2001).

New Mexico is actually one of more advanced states for legally recognizing the hydrologic connection between surface and groundwater early on. The Middle Rio Grande Basin was declared in the 1956 by State Engineer Reynolds. The State Engineer mandated pumping of groundwater requires an equal forfeit of surface water rights, thus acknowledging the hydrologic connection between the river and groundwater. Despite this known connection, the Lower Rio Grande Basin was not declared until 1980 (also by Steve Reynolds). According to the current State Engineer, Mr. Tom Blaine, the 30-year gap in groundwater basin declaration was because of the proximity to the border. New Mexico did not want to restrict their water pumping because Texas was not restricting it's use of water right across the border (Tom Blaine, personal communication, January 20, 2017). The reason the basin was declared was because El Paso was attempting to cross the state line to pump groundwater for municipal water supply in New Mexico. The designation of the Lower Rio Grande basin in New Mexico effectively stopped this from happening.

### **Texas Water Law**

*Regimes: rule of capture, riparian, prior appropriation*

“Texas’ legal system divides water into several classes—surface, groundwater, atmospheric—each of which is governed by separate legal systems.” (Wheat, 2015 p. 175). Surface water is governed by remnants of the riparian doctrine and mainly the prior appropriation doctrine (Carter, 2015). Groundwater is divided into two categories, percolating groundwater and underground streams. All groundwater is assumed to be percolating unless proven otherwise (Texas Water Law, 2014). State law does not regulate groundwater unless it falls under a “Groundwater Conservation District.” (GCD). There are 99 GCD in Texas as of February 2017 which regulate water quality, quantity, and monitor conditions of the district’s aquifers (Texas Water Law, 2014). However, there are no GCD in the Paseo del Norte study area (TWDB, 2016).

Texas is governed mainly by the prior appropriation and the rule of capture doctrines. Under “rule of capture” groundwater is essentially treated as the private property of the landowner, who has the legal right to “capture” as much as can be put to “beneficial use” (Texas Water Law, 2014). For example, Program Specialist David Gunn of the Texas Department of Licensing and Regulation explains, “if I owned a manufacturing plant where I used millions of gallons of

groundwater a day and after pumping this much water every day my neighbors' wells start to run out, so long as I can prove that the water I pump is being put to beneficial use, no judge will rule against me. This law has been in place for well over 90 years and has been challenged many times, but has never been overturned." (McCullom, 2011). The impact of this particular law directly affects industry, agriculture, and municipal use and has resulted in heavy over-pumping for agriculture all over the state (Wheat, 2015).

### Local

The cities of El Paso, Ciudad Juarez, and Las Cruces are the largest cities within the study area and must comply with state and federal water law. However, the MOU between Las Cruces and Juarez is an example of how the cities can make legally non-binding agreements.

## 1.4 Water Law Mexico

### Federal

The Mexican Government is mainly centralized when compared to the United States. However within the last decades, there has been widespread decentralization in water resource management specifically in Latin America (OECD, 2013). Some scholars argue decentralization poses risks to sustainable water management in Mexico due to specific private monopolies dominating unsustainable scenarios (Salas Plata Mendoza, 2006b).

A few notable policies have greatly aided in a more serious effort to decentralize in recent years. The 1992 National Water Law *Ley de Aguas Nacionales* established *Consejos de Cuenca* basin management councils to improve coordination between government and water users (Kelly, Bulletin 107). In 1994 a Consejo de Cuenca was established for the Rio Bravo basin but the finances and organization has been a limiting factor in actually implementing this initiative (Kelly, Bulletin 107). In 2004 Ley de Aguas Nacionales modified the Consejos de Cuenca to restructure the governance and increasing the functions (Kelly, Bulletin 107). In the 1990's the government established user associations to operate each irrigation district with the intention of creating financially self-sufficient entities (Kelly, Bulletin 107). The success of both the effectiveness and equality of these irrigation districts are heavily in question, but the system has remained in place (Rap, 2006).

In the current political administration, Peña Nieto proposed a water bill known as the Korenfeld law which attempted to privatize water, but it failed to clear congress in 2015 (BN Americas, 2017a). Most recently, the administration proposed the 2017 Federal Budget for public water system infrastructure to be cut by 72 percent (Varghese, 2016).

Groundwater is treated as public property and regulated entirely by the central government (Kelly, Bulletin 107). Under Article 27 of the Mexican constitution and the 1992 national water law, the federal government issues permits for surface and groundwater use (Kelly, Bulletin 107). The permits are issued mainly to private interests and those fulfilling needs for municipal water supply. The federal government can impose water use restrictions to prevent overexploitation of aquifers, protect or restore ecosystems, or preserve potable water (Kelly, Bulletin 107).

The most recent groundwater policy gained momentum in 2014 when CONAGUA initiated a federal groundwater movement to improve nationwide aquifer sustainability. It will be implemented through civil associations (CA) by forming Limited Liability Company (LLC) and Groundwater Technical Committee (Comite Técnico de Aguas Subterráneas, COTAS) (Castro et al., 2014). Specifically, each aquifer must have a governing Concession Agreement between the water users and CONAGUA to manage and monitor aquifer withdrawals (Castro et al., 2014). It is imperative to note how Mexico defines groundwater sustainability. “The Sustainable Water Volume” is the annual average volume available in each aquifer (quality and quantity) according to the annual average recharge. This is the maximum extractable groundwater from an aquifer and it has to be used equitably by the users of the aquifer water” (Castro et al., 2014).

### State

The state does not play a large role in water management, with most regulations stemming from the national government and implementation occurring at the local level. However due to CONAGUA’s recent effort to further decentralize, the “Juntas Centrales de Agua y Saneamiento” (Central Directorate of Water and Sewer) has become more active over the past decade in the state’s role in water management (Kelly Bulletin, 107). Future plans to improve water management include fully developing this national water rights registry in Chihuahua. CONAGUA reports the registry in Chihuahua includes 27% of water use systems, but 77% of the actual volume used (Kelly, Bulletin 107).

## Local

Salas Plata Mendoza, 2006b p. 4 states, “In Ciudad Juarez there is a scenario of unmanageable water process reflected as a lack of efficiency, efficacy, transparency and social participation (Córdova, 2006). Although JMAS is recognized nationwide as one of the best water utilities, in Ciudad Juarez the confidence on the political institutions is very low. Civic participation is led mainly by non profit organizations and NGOs.” Additional problems the municipalities face include: lack of consistent water management policy due short-term of administration of the municipal government (three years); plans and program are not based on water availability and demand management, water losses between 30 and 50%; low financing capability for operation and maintenance; Lack of consistent user data; Political and institutional problems due to monitoring deficiencies (Salas Plata Mendoza, 2006a).

To start to address these issues there are a ongoing programs run by JMAS which recognize need for sustainable groundwater- Industrial and Commercial Discharges Pretreatment Program, Groundwater Protection Program, Water Reclamation and Reuse Program (Gutierrez, 2000). In 2014 the “Juarez Water Master Plan financed through BECC has given a solid framework for future projects to the city of Juarez” (EPA, 2014). However scholars insist “practice has shown that...municipalities are not the best institutional agencies for water planning.” (Salas Plata Mendoza, 2006b p.5).

## 1.0 Results Legal Mechanisms

The legal doctrines governing the three states of New Mexico, Texas and Mexico are fundamentally different. Consequently, the levels of regulation and control for surface and groundwater are different. Most notably, groundwater quantity is regulated at the federal level in Mexico and at the state level in the United States. New Mexico has tight control on groundwater resources, while Texas law protects the landowner’s right to unregulated pumping. These scalar differences in water law can be a good indicator for who indisputably needs to be included in future discussion for joint water management. Specifically, the state level water management agencies for Texas and New Mexico, and the federal level in Mexico. Below each of the legal mechanisms are ranked according the 5-point scale, and the brief explanation follows each ranking.

- 0 – No cooperation
- 1- Partial cooperation- either groundwater quantity or quality
- 2- Low cooperation- name only
- 3- Moderate cooperation- sporadic or past
- 4- High cooperation- currently ongoing, frequent communication

<b>1. Legal Mechanisms</b>			
	MX	U.S.	Joint
Federal	3	1	1
State	0	3	0
Local	0	0	3

### 3.2.2 Governmental Institutions

Conti 2014 defines regional institutions as “international institutions whose mandate is promoting cooperation and coordination on issues of regional importance” (p. 23).

The institutions governing water in the Paseo del Norte region are institutionally complex, overlapping, and often competing for water. There is narrow middle ground given the water has been over appropriated on both sides of the border (Carter et al, 2015). Water policy decision making is made by municipal water supply entities, irrigation districts, ranch and farm associations, environmental and conservation organizations, community organizations representing low-income residents lacking access to clean water, industrial water users, academic researchers, the state water agencies, interstate compact commissions, the federal Bureau of Reclamation and, to a lesser extent, the federal Environmental Protection Agency (Kelly, Bulletin 107).

On the Mexican side, the stakeholders have similar interests but are set up differently due to the centralization of water management. SEMARNAT houses the Comisión Nacional de Aguas mainly in Mexico City and regional offices, and they hold most of the decision making authority. The other stakeholders include: irrigation districts and agricultural users associations, state and municipal water supply systems, industrial users, residents associations, and some academics and conservation and human rights organizations (Kelly, Bulletin 107).

Surface and groundwater is managed jointly by the IBWC on the international scale, federally by the Bureau of Reclamation (U.S.) and the National Water Commission (Mexico), statewide by the Rio Grande Compact Commission and specific New Mexico and Texas state laws, locally in Ciudad Juarez-El Paso, by the Texas Commission Environmental Quality (TCEQ), and the Junta Central de Agua y Saneamiento (Central Board of Water and Drainage) in Chihuahua (Sanchez, 2006). The Mexican



Constitution (Article 115) designates municipalities responsible for water supply services, drainage, sewer system, and wastewater treatment. (Kelly, Bulletin 107).

In summation, the highly managed surface water contributes to the complexity of the groundwater management. Due to the Rio Grande Project Act, the 1938 Compact and the 1906 Convention delivery obligations, the U.S. federal government is heavily involved in water management. Internationally, the IBWC is supported by the federal U.S. State Department. However, a different executive branch of the federal government, the U.S. Department of the Interior houses the Bureau of Reclamation, which is responsible for releasing the water from Elephant Butte Reservoir. The scientific branch of the federal government, the USGS is responsible for monitoring the water quality of the wells. On the state level, NMOSE provides groundwater permits, but does not manage surface water in the New Mexican Lower Rio Grande Basin unless a change in diversion point is requested. The irrigation districts in New Mexico (EBID) and Texas (EP#1) tell the BoR how much water to release from Elephant Butte and when. On the local level, water management is subject to pre-existing state and federal laws. Below I will outline the scales at which water management takes place in the Paseo del Norte region.

<b>Year</b>	<b>Treaty</b>	<b>Mexico</b>	<b>Colorado, USA</b>	<b>New Mexico, USA</b>	<b>Texas, USA</b>	<b>Agency Responsible for Delivery</b>
1906	Convention		Delivers to Mexico 60,000 AF annually in El Paso			IBWC-CILA BoR EBID EP#1
1944	Treaty Utilization of Border Waters	Delivers to U.S. 350,000 AF annually to Texas				IBWC-CILA BoR
1938	Rio Grande Compact		Delivers to New Mexico 393,000 AF annually in an average year, when 1.1 million AF of Rio Grande water flows past the CO/NM border.	Below Elephant Butte Reservoir NM EBID receives 57%, TX EP1 receives 43%. Operating agreement since 2008 has changed this to 38% to NM and 62% to TX.	Ensures delivery to Mexico is met proportional to irrigation districts.	Colorado Ground Water Commission  New Mexico Office of the State Engineer  Texas Water Development Board,  Rio Grande Compact Commission

Table 10. Treaty Obligations (adapted from, Carter et al., 2015)

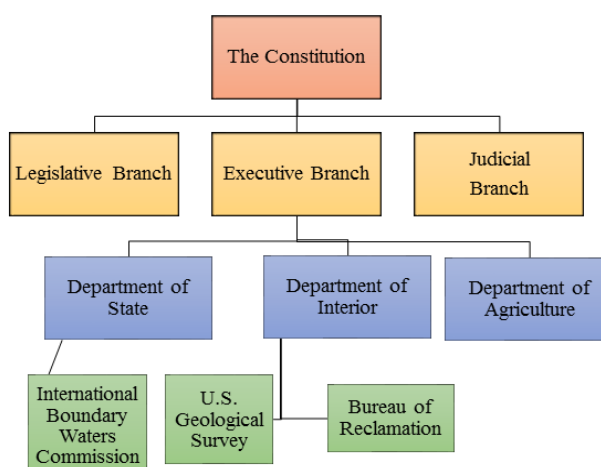


Figure 12. Relevant United States Government Organizational Structure (adapted from USA Government, 2017).

## United States

### Federal

Figure 12 illustrates the relevant water management organizations and their associated hierarchy within the U.S. government.

#### U.S. Bureau of Reclamation (BoR)

Responsible for surface water supply and including operation and maintenance of reservoirs, levees and canals.

#### U.S. Department of the Interior, Geological Survey (USGS)

Responsible for the scientific and technical aspects of research for the government. Focuses on water quality monitoring for both surface and groundwater.

#### U.S. Environmental Protection Agency (EPA)

Responsible for ensuring the water quality standards and environmental flows are met. Oversees the Border Environment Infrastructure Fund (BEIF), a result of NAFTA. The EPA is an independent federal agency, housed under the executive branch of the federal government. EPA designates endangered species under the Endangered Species Act (ESA). These listings protect animal habitat, and has potential

to override state law to implement conservation measures. There are three endangered species listed in the Rio Grande Basin, Southwestern willow flycatcher, Rio Grande silvery minnow, and New Mexico meadow jumping mouse (OSE, 2017).

## State

### **New Mexico**

#### The Office of the State Engineer (OSE)

Is responsible for managing, regulating, allocating and permitting surface and groundwater in New Mexico since 1931 (Milanes-Murcia, 2013).

#### New Mexico Interstate Stream Commission (ISC)

Works in conjunction with the OSE. Responsible for supervising and distributing surface and groundwater, specifically under the treaty and compact obligations for New Mexico.

#### The New Mexico Environmental Improvement Board (NMEIB)

Set groundwater quality standards.

#### New Mexico Water Quality Control Commission (NMWQCC)

The water pollution control agency sets groundwater quality standards

### **Texas**

#### The Texas Commission on Environmental Quality (TCEQ)

Provides permitting service for water rights claims to state surface water. Texas Commission on Environmental Quality is responsible for approving the groundwater conservation districts (GCD).

#### Texas Water Development Board (TWDB)

Responsible for all groundwater studies, approves the plans for groundwater management areas, administers the Texas Water Bank, conducts monitoring and research of groundwater issues (Wheat, 2015).

## Local

### The Las Cruces Utilities Water Section

produces approximately 6.5 billion gallons of clean, safe drinking water every year (Widmer, 2017). The city's primary source of water is the Mesilla and Jornada bolsons. This section maintains 30 wells (Widmer, 2017).

El Paso Water Utilities Public Service Board (EPWU) The only municipal service in El Paso, a monopoly which manages and operates the water and wastewater system for El Paso. This includes the operation of 105 wells in the Hueco-Mesilla bolson aquifer (Mace, Mullican, Angle, 2001).

## Mexico

The Mexican Constitution of 1917 declares all water resources in Mexican property of the government and authorizes the local governments to provide water for the public (OECD, 2013). The government has been moving slowly towards decentralization, with serious efforts seen only recently with the 1981 Federal Duties Law, 1992 National Water Law, and major revisions in 2004 to establish specific mechanisms for integrated water management (OECD, 2013). Currently the 2004 revisions, which bestow more of the water management power to state and local authorities is still pending in the secondary legislature, therefore it is not yet enforceable (OECD, 2013). State governments have the responsibility of planning, developing infrastructure projects (OECD, 2012). The municipalities in Chihuahua have turned over management to the state level, Comision de Agua, and largely deferred to the federal level, which manages water through the local municipal JMAS. The border states on the Mexican side have little influence in the affairs of the Mexican CILA, which answers to the Mexican SRE and presidential control (Sanchez, 2006).

## Federal

### The National Water Commission *Comisión Nacional del Agua* (CNA) or (CONAGUA)

The national water body largely responsible for administering water rights, groundwater regulation, charges fees for water use, funds water projects and delivers bulk water to irrigation/urban areas (OECD, 2013). It manages water at the basin level, and it has established a watershed council to manage each basin (Schmandt, 2002). This branch of the government is a separate body under the jurisdiction of SEMARNAT.

Ministry of Environment *Secretaria de Medio Ambiente y Recursos Naturales* (SEMARNAT)

This large branch of the federal government is largely responsible for the ecology, environmental sanitation, and regulation of urban pollution and fisheries (OECD, 2013)

Public Works Secretary *Secretaria de Asentamientos Humanos y Obras Publicas* (SAHOP),

Increased the number of active wells from 21 in 1970 to 54 in 1980 (Lloyd,1982)

Mexican Institute for Technology *Instituto Mexicano de Tecnologia del Agua* (IMTA)

This body under SEMARNAT conducts research to support sustainable water management (OECD, 2013)

National Association of Water and Sanitation Companies of Mexico *La Asociación Nacional de Empresas de Agua y Saneamiento de México* (ANEAS)

Non-profit civil association of state and municipal water systems. They manage drinking water operators providing legal, technical, and maintenance support (ANEAS, 2017)

Technical Aquifer Committee *Comite Tecnico de Aguas Subterraneas* (COTAS)

Department under CONAGUA specific to the Rio Bravo Watershed Council. The members are those who use the aquifer water.

## State

### **Chihuahua**

Junta Central de Agua y Saneamiento (JCAS)

Funded by water tax revenue, the largest role played is to coordinate between federal and local water management provision (JCAS, 2016). They don't regulate but are focused on sanitation and water delivery for domestic use. They play the least active role in water management of the three scales.

## Local

Junta Municipal de Aguas y Saneamiento (JMAS)

Water service in Cd. Juarez is provided by this agency. (Lloyd,1982). They are bestowed with the responsibility to provide water for citizens by the federal government, but generally not sufficient financial capital to do so (OECD, 2012). "Although JMAS is recognized nationwide as one of the best

water utilities. In Ciudad Juarez the confidence on the political institutions is very low” (Salas Mendoza, p. 206).

### *Joint Governing Bodies*

#### IBWC-CILA

In 1894, Mexico filed a formal complaint to the Secretary of Agriculture which stated Colorado’s diversions were damaging the farmers’ available water in the Juarez Valley (Cortez, 2008). As a result, the International Boundary Waters Commission (IBWC-CILA) was formed in 1889 for the purpose of jointly managing the river waters between the U.S. and Mexico (IBWC, 2009). The IBWC is composed of two sides, the IBWC on the U.S. side and CILA La Comisión Internacional de Limites y Aguas (CILA) in Mexico. The IBWC is funded by, and reports directly to the U.S. Department of State while CILA to the Mexican Foreign Affairs Secretariat (Sanchez, 2006). Leadership authority is appointed to a head Engineer (Commissioner) for both Mexico and the U.S. by the president of each respective country. Disputes are generally resolved by U.S. State Department and the Secretaría de Relaciones Exteriores in Mexico and potentially the International Court of Justice (Carter et al, 2015). The role of IBWC has expanded. Today it is responsible for communication between the two states, dispute resolution, water infrastructure, water accounting, flood control, data gathering, international problem identification, and the operation of the international dams (Schmandt, 2002 and Hamlyn et al., 2002). According to Campana and Neir (2007) the IBWC-CILA has played a fundamental role in resolving water conflicts since its inception.

On the U.S. side, the IBWC has received criticism since the 1990’s for three main issues: ignoring environmental flow requirements, not addressing issues quickly as they arise, and the lack of community involvement in water management. To address the latter concern, over the past decade IBWC has implemented the Citizen’s Forum to involve communities and it is undertaking river restoration projects. IBWC must balance the needs of the irrigation districts who want to manage the river as an efficient irrigation ditch, turning it off and on as needed, and the environmental stakeholders who want to restore the wide shallow flow and year-round water in the river (Anonymous interviewees, personal communication, 2017).

Regarding groundwater management specifically, “there is currently no binational coordination or treaty (between the U.S. and Mexico) governing the management of groundwater” (IBWC, 2012). “The IBWC

has managed largely to avoid addressing the issue of transboundary groundwater management throughout its nearly 114 years of combined operation” (Hall, 2004 p. 908). The reason for this is partly because the IBWC-CILA was set up to manage the surface water treaties. Partly because the funding and initiatives of IBWC-CILA is highly dependent on domestic politics. Third it has proven difficult to get issues and funding approved simultaneously through the bureaucratic pipelines on both sides of the border (Mike Hamman and Gilberto Anaya, personal communication, 2017). For example, for data sharing arrangements made through the TAAP initiative, scientists on both sides of the border could only communicate through the IBWC, which needed specific permissions from the state department to authorize projects and even basic communication (Anonymous interviewee, personal communication, 2017). Regarding future options for sustainable water management in the basin it is crucial to not to confuse the IBWC-CILA diplomatic role, with a more scientific knowledge of groundwater.

## 2.0 Results Governmental Institutions

The differing fundamental arrangement of the institutions in the United States and Mexico make it difficult to jointly management transboundary water resources. These agencies are a direct reflection of the respective water laws. As such, the main difference is regulation agencies exist at the state scale in the United States and at the federal level in Mexico. While joint management of IBWC-CILA’s role is to facilitate cooperation to ensure both sides are managing water in accordance with the treaties, there are agencies in both countries that are more qualified responsible for the scientific and systematic aspects of water management.

<b>2. Governmental Institutions</b>			
	MX	U.S.	Joint
Federal	4	3	3
State	2	4	0
Local	4	4	2

### 3.2.3 Third party Involvement

Conti 2014: “when an entity that is not one of the aquifer-state governments contributes significantly to the cooperation process... via formal programs or partnerships.” (p.24)



To avoid overlap between the categories, third party involvement is defined here as an entity other than the United States or Mexican government. Although third party involvement would normally be considered just foreign investors, for this research the remaining parties can be characterized generally as non-governmental organizations, foreign investors, irrigation districts, and universities. The drivers for third party involvement are often specific to the values each entity represents. For example, economic trade drives the involvement of outside investors and development banks. Concern for the environment drives non-profit and non-governmental organizations to act. Examples of active third party entities are found below. Each one of the entities mentioned has contributed to one of the previous water cooperation examples mentioned in section 3.5.

#### Non-governmental organizations

##### El Paso del Norte Task Force

on citizens and professionals from New Mexico, Texas and Chihuahua in the Rio Grande. They are studying the population growth, land use, water supply and demand to better understand the feasibility issues of the legal, financial and management arrangements for cross-border planning (Schmandt, 2002).

#### Universities

San Diego State University, El Colegio de la Frontera Norte, The Udall Center at the University of Arizona, Utton Transboundary Resources Center, University of New Mexico, and the New Mexico Water Resources Research Institute, New Mexico State University.

#### Environmental

The Southwest Consortium for Environmental Research and Policy (SCERP) - and organization that assesses groundwater quality and socio-economic status along border towns in New Mexico

#### Foreign investment by International Corporations

Cheap labor and NAFTA is a driver for the maquiladora industry. Companies like Honda, BMW, Ford, General Electric, and Sony have invested in the maquiladora industry in Mexico. These factories account for a percentage of the groundwater consumption. Foxconn and Union Pacific have built large facilities and a private highway in Santa Teresa, NM 10 miles from the Ciudad Juarez border.

### Irrigation Districts

EBID and EP#1 are the two irrigation districts charged with allocating the water from the Rio Grande project. These public entities play a significant role in water management in the study area.

### Citizen's Forums

These were recently created as response to the IBWC-CILA being criticized for being too non transparent and non participatory. These public forums provide an opportunity to exchange information to solve regional problems between the IBWC-CILA and the public (Milanes-Murcia, 2013). These forums could also potentially act as conflict resolution platforms for transboundary groundwater issues (Brown, 2005).

## 3.0 Results 3rd Party Involvement

<b>3. Third-Party Involvement</b>			
	MX	U.S.	Joint
Federal	2	0	0
State	0	2	0
Local	3	3	3

### 3.2.4 Previous Water Cooperation

Conti 2014 “Cooperation does not necessarily occur between all the aquifer states, nor must it to be cooperation specifically with respect to groundwater resources. For counties spanning large geographic areas, cooperation may not occur in the specific region where the aquifer is located, but rather between the states themselves. Analysis shows that willingness to dialogue about water resources in the past, especially within a strong institutional setting, indicates a continued willingness to do so in the future.” (p. 24). This section expands upon the idea of cooperation in relation to agreements across all sectors.

It is important to clarify who is cooperating or not cooperating over resources in this section. For example, in the U.S. on a state to state level, the state governments are currently not cooperating. “I would describe the current Supreme Court case more as Austin suing Santa Fe. Not EP#1 suing EBID”. (Dr. Phillip King, EBID consultant, personal communication, January 23, 2017). These two states have been engaged in litigation for the past 40 years. Admittedly, “sometimes litigation is necessary to hit people over the head with a 2x4 so they will go back to the negotiation table.” (Anonymous interviewee, personal communication, January 2017).

Regardless, the governor of each state appoints members to sit on the Rio Compact Commission, which jointly allocates the water according to the Compact. Despite the litigation, this Compact has proved to be resilient thus far (Mike Hamman, Middle Rio Grande Conservancy District, personal communication, January 26, 2017). Yet across the NM/TX state border, the local irrigation districts communicate daily with the IBWC and BoR, federal agencies (Gary Esslinger and Jesus Reyes, personal communication, January 2017). Therefore, although the level of cooperation over water resources is high, the level of conflict is high as well.

### **Bellagio Draft Treaty**

The first effort which recognized U.S.-Mexico transboundary resources was a joint initiative between Professor Albert Utton and Ambassador Cesar Sepulveda. In 1977 the Transboundary Resources Study Group was formed to examining the growing problems of transboundary aquifers along the two countries, extensive border (Utton and Hayton, 1989). The draft provides mechanisms for the international aquifers in critical areas to be managed by mutual agreement rather than continuing to be subjected to unilateral leaking. The treaty addresses contamination, depletion, drought and transboundary transfers as well as withdrawal and recharge issues. The authors recognize that attempting to predict the political dynamic, both domestic and international, would be a pointless, pretentious exercise because the politics are so often controlled by extraneous factors and impossible to predict (Utton and Hayton, 1989). Instead the aim was to deliver a legally adequate set of provisions based on scientific knowledge, sensitive to the border dynamics.

“At its heart, the Bellagio treaty was a call for rational, scientific management of the transboundary aquifer through a bi-national Commission and a corresponding database containing the measurements and quality analysis of the transboundary aquifers.” (Schaefer, 2009). This treaty marks the first serious

transboundary aquifer cooperation effort in the Rio Grande basin while also providing a platform which to base a future international agreement.

### *Economic Cooperation*

Every day there is \$1.5 billion in bilateral trade across the US/ Mexico border (White House, 2016). A staple of economic trade between the U.S. and Mexico is the maquiladoras industry. This trade started in the 1960's and by 1992, the plants provide employment for half a million Mexicans and export \$19 billion annually, roughly 40 percent of Mexico's worldwide exports (Council on Foreign Relations, 2017). The trade works by the United States shipping raw material across the border to Ciudad Juarez and other border cities, effectively outsourcing cheap labor to the manufacturing industry across the border. Bill Sanders, an El Paso real estate investor explains, "The United States is the largest consumer market in the world, and the most efficient place in the world to produce those goods is on the U.S.-Mexican border" (Villagran, 2016). Discussed in detail below, the NAFTA agreement greatly bolstered the maquiladora industry in Mexico since the 1990's. However, in some aspects this negatively affected El Paso with an estimated loss of 14,000 jobs which were replaced by cheaper labor just across the border (Lardner, 2001). In addition to the trade of textiles, there's the hidden economy of the drug trade, between the U.S. and Mexico which experts estimate contributes between \$6 billion and \$36 billion a year (Rice, 2011).

The economic growth for the region can be summarized as follows, "From 2001-2006, the combined GDP for the El Paso and Las Cruces grew 36% versus 30% for the United States as a whole. In the case of Ciudad Juárez no official data is available at municipal level, but the State of Chihuahua has improved from 6th in the early 2000 to the 5th highest Per Capita GDP in the nation." (Regional Stakeholders Committee, 2009).

In short, in Ciudad Juarez, Mexico's economy and water use lies most heavily in the maquiladora industry. In contrast, agriculture is the main driver of the economy in southern New Mexico and west Texas. In addition to New Mexico's \$182.5 million a year pecan industry other major crops include chili peppers, onion, and alfalfa (Villagran, 2016).

### **North American Free Trade Agreement (NAFTA)**

January 1994 the North American Free Trade Agreement was approved by a congressional executive agreement by U.S. President Bill Clinton (Jacobson, 2015). NAFTA is a trilateral economic agreement

between U.S., Canada, and Mexico to eliminate tariffs and enhance trade between North American states. In addition to trade, new institutional relationships were formed to cooperate over environmental degradation along the border, central bank cooperation, and military training. (Council on Foreign Relations, 2017). The main institutional arrangement that has stemmed from NAFTA in the study area is the BECC which carries out initiatives through the BEIF and NADBank. This new branch has allowed side agreements to be made through NAFTA to construct wastewater treatment plants along the border because water quality has become such a substantial issue in border towns (Schmandt, 2002).

### **Border Environment Cooperation Commission (BECC)**

The goal of the BECC is to “help preserve, protect, and enhance the environment of the border region for the people of the United States and Mexico” (Brown, 2005). They provide technical support to local and regional efforts to build infrastructure to improve environmental quality (Schmandt, 2002). They have maintained a fairly open, participatory, and transparent policy and decision making process (Megdal et al., 2011). Within the BECC, the Border Environment Infrastructure Fund (BEIF) is currently working to create potable water and wastewater plants along the border (EPA, 2016). “Between 2003 and 2013, the program has significantly reduced waterborne diseases by providing more than 63,300 homes with first-time access to safe drinking water and more than 569,800 homes obtained first-time access to wastewater treatment services.” (EPA, 2016). “Ciudad Juarez now has capacity for treating 100% of its municipal wastewater” (EPA, 2014).

There is previous water cooperation also occurring among the scientific community. However, because the next section entirely devoted to the scientific aspect, this section focuses primarily on the economic cooperation.

#### **4.0 Results Previous Water Cooperation**

<b>4. Previous Water Cooperation</b>			
	MX	U.S.	Joint
Federal	3	3	2
State	0	4	0
Local	3	3	3

### 3.2.5 Scientific Research

Conti 2014: Scientific research is considered an Enabling Factor if it is conducted specifically for the assessment of transboundary impacts and provides the aquifer states with a significant amount of new information about the aquifer. The research must occur prior to any informal or formal political cooperation on groundwater resources. This could include investigating the physical characteristics of the aquifer, such as extent, depth, storage volume, transmissivity, as well as recharge and discharge areas. It could also include information on groundwater quality, groundwater uses (human and environmental) and analysis of threats to overall sustainability.” (p. 24).

Both the United States and Mexico recognize a better scientific understanding of aquifer systems would aid tremendously in the planning and management of water resources (Callegary et al., 2016). In 1997 the IBWC the aquifers in the Paso del Norte region were mapped and characterized by the state agencies (Schmandt, 2002). However the most robust effort for joint scientific collaboration came with the authorization of the 2006 TAAP project, which spurred a binational scientific effort August 2009 with IBWC-CILA signing the “Joint Report of the Principal Engineers Regarding the Joint Cooperative Process United States-Mexico for the Transboundary Aquifer Assessment Program” (IBWC-CILA, 2009). This joint report is the foundation for U.S.-Mexico coordination and dialogue to implement transboundary aquifer studies (Callegary et al, 2016). The arrangement stipulates roles, responsibilities, funding, relevance of the international water treaties, and data sharing information (IBWC-CILA, 2009). The TAAP is the manifestation of many of the legal principles outlined in the Bellagio Treaty.

### **TAAP**

The U.S. – Mexico Transboundary Aquifer Assessment Act (TAAA) (Public Law 109-448) was signed into law by George Bush, President of the United States on December 22, 2006, with the aim of conducting a scientific, joint binational assessment of transboundary aquifers (Alley, 2013). Congress authorized TAAP with a total project budget of \$50 million for 10 years between 2007-2017 (Megdal and Scott, 2011), however only about 3 million has been actually appropriated from Congress (Dr. Chris Scott and Dr. Sharon Megdal, personal communication, March, 2017). There were four transboundary aquifers designated for priority assessment: the Hueco and Mesilla bolsons in El Paso-Ciudad Juarez, and the Santa Cruz and San Pedro aquifers in Arizona-Sonora (Callegary et al., 2016). Each state took a different

approach to mapping of aquifers. Arizona prioritized including a diverse group of stakeholders (Dr. Chris Scott, personal communication, March 2, 2017). One of the notable results of the Arizona effort was the “Binational Study of the Transboundary San Pedro Aquifer” the result of the Mesilla was the “Hydrogeological Activities in the Conejos-Medanos Aquifer 2010” which covers solely the Mexican side of the Mesilla bolson, and the Hueco bolson research is still currently in progress. One of the strengths of TAAP, and most likely why it was successful was because it did not focus on issues of sovereignty but instead on the virtues of joint data gathering (Megdal, 2013).

### Summary

TAAP is a U.S. federally mandated and funded scientific venture. Joint cooperation from the Mexican side was voluntary. IBWC-CILA provided administrative support to help authorize many of the joint data sharing arrangements. Funding was allocated through USGS, and the three respective land grant state universities led the effort to jointly gather hard scientific research. Generally speaking, partnerships were formed across state and country borders between local scientists. This category is unique because it is the only category in which U.S. and Mexico receive the same ranking. Given the separate measurements, differences in technology, and the language barrier, scientific cooperation across the border is exceedingly difficult. Joint cooperation efforts for shared data gathering and analysis was successful.

## 5.0 Results Scientific Research

<b>5. Scientific Research</b>			
	MX	U.S.	Joint
Federal	3	3	4
State	3	3	0
Local	1	1	0

Ingram and White 1993 summarize, the IBWC is exemplary for the mission of solving water related disputes between the two countries, but it is so deeply ingrained in the bureaucratic processes it is far from being truly a flexible, adaptable binational agency. Although the IBWC has received criticism in the past, it is important to keep in mind the purpose of the agency one of diplomatic discourse and dispute resolution, not specific technical.

### 3.2.6 Funding Mechanisms

Conti 2014 stipulates funding mechanisms can be provided by either the state in which the aquifer is situated, or a third party. “Availability of domestic financial resources has a noticeable impact on organizational capacity in that those with less financial resources tended not to display a high-level of capacity in groundwater resource management” (p.24).

Loans and grants are provided largely by both the U.S. and Mexican federal government and secondarily by the state governments. For example, funding for the TAAP project was funneled through USGS, which distributed funding among the three lead universities in each state. As part of NAFTA, the “EPA supplied \$170 million in start-up funds for water and wastewater projects” (Frisvold and Caswell, 2003). Through grants and other outside sources, the universities can apply for funding largely on a project by project basis. The state of Chihuahua provides funding for environmental sanitation and water projects (Two year action plan, 2013). The disparity in economic development has led to differences among priorities between the two countries’ enthusiasm and capacity to fund water related activities. “U.S. GDP per capita is nine times Mexico's” (Frisvold and Caswell, 2003). These difference have led to significant investment from development banks in Mexico although Pérard, 2009 states both the U.S. and Mexico have between 10-30% private investment in the water sector.

Privatization of water infrastructure has been pushed heavily by the current Mexican administration, although it has received significant resistance from the public. According to Varghese 2016, “The World Bank and Veolia are investing in every aspect of the Mexico City's water infrastructure.” As part of the Conejos-Medanos San Jeronimo well field project, the Chihuahuan government awarded a ten year concession to Carso Infrastructure and Construction company (CISCA) to sell water to Ciudad Juarez’s municipal government (Ciudad Juarez-Chihuahua News, 2007). CISCA is one of over 200 companies owned by Carlos Slim, Mexico’s richest billionaire; other investments by Mr. Slim in Chihuahua include the mining industry, telephone and television networks (FSN News, 2010).

### WorldBank Group

The World Bank has financed loans for projects related to public works, water and sanitation through BANOBRAS (Lloyd, 1982).



### North American Development Bank (NADBank)

Created by NAFTA to fund environmental projects. In Ciudad Juárez, there are many municipal wastewater projects financed by NADBank and implemented by BECC (Kelly, Bulletin 107).

### Border Environmental Infrastructure Fund

With the purpose of transitioning to a more locally self-financing system, the U.S.

EPA and NADBank established the BEIF (Frisvold and Caswell, 2003). Over 95% of NADBank's \$265 million in approved grants has been towards BEIF grants (Frisvold and Caswell, 2003).

### Banco Nacional de Obras y Servicios Públicos (BANOBRAS)

Mexico's federal public works bank (Lloyd, 1982).

## 6.0 Results Funding Mechanisms

Funding was described by interviewees as one of the most limiting factors for the joint research and cooperation over groundwater research. The majority of funding for projects concerning scientific research is channeled through universities and the federal government, while funding for public water supply systems comes from local government in the U.S. and national government in Mexico. Funding for infrastructure comes from the federal government in both countries. International banks play a large role in funding sanitation and development projects in Mexico, although there has been significant public push back against privatization.

<b>6. Funding Mechanisms</b>			
	MX	U.S.	Joint
Federal	3	3	4
State	3	3	0
Local	1	1	0

### 3.2.7. Political Will

Conti 2014: “A particularly strong indicator of political will is when persons at the ministerial or executive level actively advocate for international cooperation for the aquifer. Open verbal support as well as the facilitation of diplomatic events, such as hosting meetings or negotiations, are examples” (p.24).

I recognize this section is the most subjective but because it is such a powerful part of bilateral water sharing, it could not be excluded. Political influences over water cooperation and conflict are largely ignored even though politics plays a large role across all scales (Zeitoun & Mirumachi, 2008). To help address the inherent subjectivity I have listed which aspects of political will this assessment includes. The analysis is based from the assumption in both the United States and Mexico, the *collective* political will is largely divided among parties and cannot be measured or classified as a unified whole. For example, the public doesn't always agree with elected state officials, who don't always agree with the president. I acknowledge I will not be able to wholly characterize both the entire collective political will across scales in both countries. Although past foreign relations are important for understanding our current situation, and future predictions could be helpful, only current political will was included in this assessment.

There are few important distinctions. Political will is difficult to measure because:

- 1) Political will is a small subsection of politics
- 2) Often individual political will is confused with collective political will. The distinction must be made before attempting to measure either.
- 3) The motivating factors driving individual political will are focused around unquantifiable relationships,
- 4) Power dynamics are a fundamental part of political will.

First, political will is a small subsection of politics. As such, it is only part of the explanation for any political outcome. I acknowledge only a very small part of political will is assessed, and that part is only a small part of the larger foreign politics.

Second, there is a major distinction between collective political will and individual political will. The existing literature describes collective political will in many forms, but there is a gap in identifying and measuring individual political will. The driving force behind individual political will is usually the

enhancement of this individual's reputation or influence. These two concepts are inextricably linked. "It is impossible to ignore the leadership and personal investment on the part of individual actors that contribute to the generation and maintenance of political will at the collective level. (Kapoutsis et al., 2015 p.2)"

Third, individual relationships between the politicians, constituents, and immediate networks motivate specific policy or media decisions (Kapoutsis et al., 2015). This helps explain why is difficult to define, measure, and assess constantly changing social constructions interlaced with hidden incentives and irrational behavior.

Fourth, "Transboundary water interaction is above all a political process subject to the whims of power." (Zeitoun & Mirumachi, 2008 p. 299). Often the political will built around decisions over water is linked larger political enterprises driven by "securing development of different economic sectors, keeping national integrity or defending regional interest, or mainly rewarding some power elite groups" (Van Steenberghe, Kumsa, and Al-Awlaki 2015 p.775). An example of water cooperation wrapped into a larger political dynamic is the Chamizal dispute, discussed later in this section.

The influence of the drug cartels in Mexico should be mentioned because they are powerful enough to control the politicians and government officials. The narcotics trade between the U.S. and Mexico has impacted the water sector indirectly in two ways, political will has prioritized the immediate violence and the drug cartels' corruption of government officials.

Eckstein 2014 proposes the reasons there has not been political will on the federal level to create an agreement could be because of the reluctance of politicians to delve into water security issues, or simply because it is low on the priority list relative to immediate issues of the country. As they are in different stages of development, Mexico's federal political priorities are different than the United States. Generally, topics of discussion on the political agenda in the U.S. are boosting of the economy, healthcare reform, strengthening national military/defense, and immigration reform (CNBC 2017, Washington Post 2017, Fox News, 2017). In contrast in Mexico the political agenda has been centered around decreasing the violence associated with the drug cartels, passing new anti-corruption laws, and economic inequality (Gobierno Mexicano, 2016; Time, 2012).

The drug trade has been described as “is both symbiotic and parasitic, with the U.S. being the parasite” (Rice, 2011). In 2010 there were over 3,000 homicides in Ciudad Juarez effectively topping the list of one of the most dangerous cities in the world, while directly across the border there were 5 homicides that year in El Paso (Rice, 2011). These numbers have since decreased in Juarez. Despite the proximity to one of the most dangerous cities in the world, El Paso has boasted on being one of the safest cities in the world. This is partially attributed to the large array of DEA, ICE, Army and law enforcement headquarters in El Paso and over 2.3 billion appropriated by the U.S. Congress since the Merida Initiative for tighter border security in 2008 (U.S. Department of State 2015). The violence taking place daily in Juarez is enough to keep politicians on all scales busy with more pressing priorities than planning for a secure water future.

While public and private sector corruption happens on varying degrees in every country, in Mexico, there is a dangerous link between government officials and the powerful drug cartels (U.S. Department of State 2015; Minjáles, 2014). The cartels use violence, intimidation and threats to effectively convince government officials to protect illegal activities. Prosecution for illegal activities has been slow, which has impacted the ability of the government to enforce laws and operate effectively (U.S. Department of State 2015). The full impact of corruption on the water sector is unknown, but the influence of the cartels to some degree in the water sector through politicians or government officials is most likely occurring.

The literature suggests measuring political will as both the level of support and level of influence (Kapoutsis et al., 2015 and Stachowiak et al, 2016). Therefore I have attempted to gauge the political will based on this measurement which generally accounts for a small part of the collective will (based on the people who elected the politician), and a larger weight on the individual political will.

To assess political will, I searched news articles and policies for evidence of cooperation over water resources. I used level of support based on approval ratings of the major political leaders on the federal and state scales. On the local scale, since approval ratings don't apply, I searched recent news articles for cooperation over water resources. Joint cooperation was assessed by examining the current political climate between the two presidents.

## *Past U.S./Mexico Foreign Relations*

### **Chamizal Dispute**

Water was used as a bargaining chip in part of larger political agreement. There was an ongoing disagreement over the land when the Rio Grande changed course between El Paso and Ciudad Juarez. The Chamizal Dispute was not resolved for 100 years. Between 1852 and 1868, the Rio Grande shifted and 600 acres of land that was formerly in Mexico was moved to the El Paso side of the border (National Park Service, 2017). Various presidents tried to reach consensus for 100 years. It wasn't until the Cuban Missile Crisis in the 1960's that brought the two countries together to talk. Mexico was not cutting ties with Fidel Castro, which made the U.S. nervous about being vulnerable in the Cold War. John F. Kennedy signed an agreement with the Mexican President Adolfo López Mateos in January 14, 1963, to cede over half the land to Mexico and share the cost of dredging a new channel and paving the Rio Grande riverbed between the two cities (National Park Service, 2017).



Figure 13. Depicts the concrete channel constructed between El Paso and Ciudad Juarez. The lining of the river has directly impacted recharge to the Hueco bolson and Rio Grande Aquifers. (Rice, 2011 New York Times)

During the Obama Administration (2009-2016) initiatives were signed enhancing educational initiatives for student exchanges programs, environmental protection, climate change and energy with both countries signing the Paris Agreement, cooperation over Zika virus combat strategies, and High-Level Economic Dialogue (HLED) (White House, 2016). At this time foreign relations on water cooperation were focused on Mexico's lack of delivery for water under the 1944 Treaty. According to an anonymous interviewee, there is conflict between the states of Mexico in the Rio Grande/Bravo basin regarding responsibility for

meeting 1944 treaty obligations. In 2013, Mexican president Enrique Peña Nieto requested his Foreign Ministry to prioritize working with the IBWC to resolve differences over the 1944 Treaty. In December 2014, U.S. Congress approved the Consolidated and Further Continuing Appropriations Act (Carter et al, 2015). It requires the U.S. Section of the IBWC to report on appropriations on water delivery issues specifically related to the 1944 Treaty below Fort Quitman. The goal is to ensure Mexican water deficits are made up during the next cycle.

### *Current U.S./Mexico Foreign Relations*

Since the election of President Trump, who was inaugurated January 20th 2017, the US/Mexican relations have been on less stable ground. Former Governor of New Mexico, Bill Richardson said “the U.S.-Mexico relationship is in the worst shape that I've seen in the last 35 years” (NPR, March 29<sup>th</sup> 2017). January 25<sup>th</sup>, 2017 President Trump signed the “Border Security and Immigration Enforcement Improvements” executive order, calling for a 10 billion dollar wall to be built on the border of U.S. and Mexico. The Wall Street Journal reports, along with this executive order came the promise that, “In some way or another Mexico will reimburse us for the cost of this wall.” (Cordoba et al., 2017). The same day President Trump released this statement, President Peña Nieto released a statement strongly stating Mexico would not pay for this wall (Cordoba et al., 2017). According to the 1970 Boundary Treaty, both sides of IBWC-CILA must agree if either side is to build a structure that would affect the floodwaters of the Rio Grande/Bravo river (NPR, April 25<sup>th</sup>, 2017). Since the sides do not currently agree on building a wall, for the U.S. to build this wall would be in direct violation of the treaty (NPR, April 25<sup>th</sup>, 2017). According to a fact sheet released by the new administration January 25th 2017 U.S. relations with Mexico are “strong and vital” (Department of State, 2017) however, there has been no mention of water.

### *Power*

Power is defined as the capacity to impact the surrounding world and the capacity to dominate other beings (Lukes, 1986). Power is a fundamental aspect of the greater political dynamic. On the international scale, Mexico and the United States belong to several the same international organizations, including the Asia-Pacific Economic Cooperation (APEC) forum, Organization for Economic Cooperation and Development (OECD), International Monetary Fund (IMF), World Bank (WB), and World Trade Organization (WTO) (Department of State, 2017). Under the current presidential administration, Mexico is more interested than the U.S. in working with the United Nations.

The trail of power can be followed. The United Nations Sustainable Development Goals on water are being led by the World Bank Group. The relationship between the World Bank and Mexican Peña Nieto is very close. Interestingly, the newly formed High level Panel on Water is being headed by the President of Mexico, Enrique Peña Nieto, who has been pushing water privatization reforms in Mexico. (IATP 2016). “With the World Bank now positioning itself as a leader in the implementation of the SDG on water, groups who fought for a rights-based perspective are now deeply concerned that the agenda will very quickly be steered away from human rights objectives in favor of a plan to manage water to meet the World Bank’s vision for economic growth” (IATP, 2016).

### *Approval ratings*

- In January 2017 President Peña Nieto has a low approval rating of 12% according to a poll published in the Reforma (USA Today, 2017).
- In January 2017 President Trump had a 40% approval rating, the lowest of any incoming U.S. president (Washington Post, 2017).
- At the end of 2016 the former governor of Chihuahua, Cesar Duarte had a 32% approval rating (EFE, 2016). He has since been charged with corruption, found guilty, and been replaced. The newly elected governor does not yet have an approval rating.
- At the end of 2016 Susana Martinez, the governor of New Mexico had a 50% percent approval rating (Morning Consult 2016).
- At the end of 2016 Greg Abbot, the governor of Texas had a 63% percent approval rating (Morning Consult, 2016).

## 7.0 Political Will Results

7. Political Will			
	MX	U.S.	Joint
Federal	2	0	0
State	1	1	0
Local	2	2	3

### *3.2.8 Overall Institutional Capacity*

#### Research Questions:

1. What are options to sustainably manage transboundary groundwater?
2. How can legal, economic and scientific options contribute to the more sustainable management of transboundary groundwater across scales [local, state, national and binational]?
3. Institutions are best equipped to jointly manage groundwater across which scales?

In order to answer the research questions, I conducted an institutional analysis of the current groundwater management situation. Knowing on which scale institutions currently manage groundwater is critical to developing future options for more sustainable management. Within the Conti framework, high institutional capacity is one of the 8 factors that contribute to the overall assessment. Here Conti defines institutional capacity as, “when organizations (including governments) within the aquifer states have demonstrated an ability to address water management issues. This high-level of capacity is demonstrated by organizations executing significant portions of projects related to groundwater monitoring, modeling or management” (p. 24). The methodology for this research further refines the findings of Conti 2014 by narrowing the definition of institutional capacity.

The literature makes the distinction between two types of institutions- informal and formal. The definition between the two types is best described by Pahl-Wostl, et al, (2008 p. 485) where institutions are “the formal and informal rules that provide the framework for the behaviour of human beings. Formal institutions include laws and regulations, formal organizational structures and formal procedures. Informal institutions refer to socially shared rules and norms that have developed in social practice.”

This analysis is focused foremost with the formal institutions such as the hard laws, existing governmental agencies, and scientific research surrounding groundwater. However, the informal institutions which are more difficult to classify, are captured in the sections for political will, previous water cooperation and third party involvement. I recognize this list is not exhaustive, there are many more informal institutions that are excluded from this study due to difficulty to measure and time constraints. For the purpose of this research, institutional capacity can be defined as the seven factors which contribute to the overall ability of the basin to manage groundwater [Legal mechanisms, governmental institutions, third party involvement, previous water cooperation, scientific research, funding mechanisms, political will]. This assessment will contribute directly to the overall goal of identify options



across scales for sustainable management of transboundary aquifers. By independently assessing each countries capabilities and the joint existing management structures, I can determine which scales have the most potential for cooperation (See Tables 11, 12 and 13).

#### 8.0 Results Overall Institutional Capacity

<b>Institutional Capacity Index</b>			
	MX	U.S.	Joint
Federal	3	2	2
State	1	3	1
Local	2	2	3

Scale	1 Legal Mechanisms			2 Governmental Institutions			3 Third-Party Involvement			4 Previous Water Cooperation			5 Scientific Research			6 Funding Mechanisms			7 Political Will			Institutional Capacity Index		
	MX	U.S.	Joint	MX	U.S.	Joint	MX	U.S.	Joint	MX	U.S.	Joint	MX	U.S.	Joint	MX	U.S.	Joint	MX	U.S.	Joint	MX	U.S.	Joint
Federal	3	1	1	4	3	3	2	0	0	3	3	2	4	4	4	3	3	4	2	0	0	3	2	2
State	0	3	0	2	4	0	0	2	0	0	4	0	3	4	3	3	3	0	1	1	0	1	3	0
Local	0	0	3	4	4	2	3	3	3	3	3	3	4	4	4	1	1	0	2	2	3	2	2	3

Table 11. Compiled Ranking

### Color Rank Description

	0	No cooperation
	1	Partial (quantity or quality)
	2	Low Cooperation
	3	Moderate cooperation
	4	High cooperation

Table 12. Cooperation Legend

Scale	1 Legal Mechanisms			2 Governmental Institutions			3 Third-Party Involvement			4 Previous Water Cooperation			5 Scientific Research			6 Funding Mechanisms			7 Political Will			Institutional Capacity Index		
	MX	U.S.	Joint	MX	U.S.	Joint	MX	U.S.	Joint	MX	U.S.	Joint	MX	U.S.	Joint	MX	U.S.	Joint	MX	U.S.	Joint	MX	U.S.	Joint
Federal																								
State																								
Local																								

Table 13. Final Institutional Capacity Index Results

### 3.3 Results from Interviews



Figure 14. The Rio Grande/Bravo River outside of Las Cruces, New Mexico, January 2017

(Image credit, Christina Welch)

Figure 14 captures the dryness of the region and the minimal flow of the Rio Grande river during non-irrigation season, January 2017. The opinions of those interviewed provide valuable insights to how groundwater is viewed in the Paseo del Norte region. The contents of the interviews were compiled and grouped into three main categories- stakeholder dynamics that can lead to future cooperation or conflict and the options stakeholders proposed as paths forward. My own proposed solutions in the next section are based from what the interviewees recommended and options I found through an extensive literature review.

#### Agreed barriers to Cooperation:

- Funding was identified by almost all stakeholders as the biggest limiting factor. Specifically, on a federal level, the lack of synchronization between Mexico and United States funding has proved to be nearly impossible to maintain the continuity of projects (Megdal, Scott, and Anaya, personal communication, 2017).
- Litigation destroys trust and often legally forces defendants to stop communicating during litigation.
- The differing state water laws for New Mexico and Texas reveal completely different conceptual models for how decision makers approach decisions. Specifically, Texas does not regulate groundwater if it is outside of a groundwater conservation district. Here the right to pump, or “rule of capture” is tied directly to the land right. In New Mexico, all water is regulated by the

State Engineer, but because of the Rio Grande Project, irrigations districts have control of the surface water in the Lower Rio Grande Basin.

- The language difference, disparity among measurement units, and different parameters of measurement were agreed on by most stakeholder to not be barriers, but hurdles which could be overcome with time and patience (Sharon Megdal, University of Arizona, personal communication, March 21, 2017).

#### Agreed facilitator of Cooperation:

- Time. It takes time to build the relationships.
- Mutual respect. This was mentioned many times by the stakeholders which have years of experience working across the border (personal communication with Megdal, Anaya and Scott, March 2017). “We cannot presume to tell Mexico what to do” (Gilberto Anaya, IBWC Chief of Environmental Division, personal communication March 13, 2017).
- Economic development. No one wants to agree to anything that is going to limit economic development (Gilberto Anaya, IBWC Chief of Environmental Division, personal communication March 13, 2017). It’s scary and unprecedented to put a cap on groundwater use. Over the years, water managers in the basin have effectively allocated all the surface water. Should groundwater be allocated to preserve it?

#### Spectrum of existing Conflict and Cooperation

- “I hope our work on transboundary aquifers on the border [US/Mexico] sparks conflict at the federal level because at least this would mean attention. Something needs to be done.” (Anonymous interviewee, March 2017).
- “Cooperation requires mutual benefit. Unless the benefit is no more lawsuit, it is hard to find that within the Rio Grande Compact because in order for someone to get more water, someone else has to get less. That’s not cooperation. That’s resolution. There is opportunity for resolution within the Compact disputes but there is opportunity for cooperation between various geopolitical entities for harnessing resources that are currently not harness-able” (Anonymous Pecan Farmer in the Lower Rio Grande Basin, personal communication January 2017).

- Scientists have adapted to the new political climate by excluding certain words from reports, like “transboundary” or “cooperation.” They are continuing the same research, and submitting the same grant proposals, just with a different choice of words (Anonymous interviewee, personal communication 2017).
- “There’s not a race to the bottom going on right now” (Anonymous pecan farmer in the Lower Rio Grande Basin, personal communication January 2017).
- “In order to make enough for Mexico’s delivery EBID will shut an upstream diversion to share the losses with EP#1.” (Dr. Phillip King, EBID consultant, personal communication, January 23, 2017)
- “We are tightening our belt up here. We are cognizant that we need to be more efficient. The better we [Middle Rio Grande Conservation District] do, the better off our friends and neighbors in El Paso will be.” (Adrian Oglesby, Middle Rio Grande Conservancy Board Member and Director of Upton Transboundary Resource Center, personal communication, January 20, 2017)
- “We need to manage these water resources regionally instead of in accordance with what the geopolitical boundary tells us to do because we have the same problems. We have the same problems as Texas and Mexico” (Tom Blaine, New Mexico State Engineer, personal communication, January 20, 2017).

Possible options for future management listed by stakeholders:

- Re-negotiating the treaties was not an option according to *everyone interviewed* as well as the published literature on the subject (Carter et al., 2015; Schmandt, 2002). The principle reason is both the U.S. and Mexico have “too much to lose” by putting everything back on the table.
- Amending the 1944 Treaty through the Minute process, though this option was not popular, and would need to include highly specific provisions for a new agency or arrangement for implementation.

- Creating a new treaty specific to groundwater. All of the major water managers with positions of power in the basin interviewed agreed this was the best legal option. The reasons are: each aquifer is unique and has different hydro-geologic boundaries than surface water; the surface water treaties and agreements do not include adequate provisions to manage groundwater; a new treaty would carry significant political weight, and ideally funding.
- A joint model is the next feasible step to scientific cooperation. It is widely agreed on that before an agreement is made, there must be modeling of the Mesilla and Hueco bolsons. The TAAP initiative provided the funding and political will to get this effort off the ground, but this is the last year for the funding. The logistics of implementing joint modeling is currently being discussed between Texas and Mexico and overseen by IBWC-CILA.
- Joint economic development between New Mexico and Mexico was proposed, but with the caveat of significantly more scientific research of the Mesilla bolson in southern New Mexico to enable planning for possible restraints on economic growth.

## CHAPTER IV. DISCUSSION

### 4.1 Analysis of Results

#### Research Questions:

1. What are options to sustainably manage transboundary groundwater?
2. Institutions are currently best equipped to jointly manage groundwater across which scales?
3. How can legal, economic and scientific options contribute to more sustainable management of transboundary groundwater across scales [local, state, national, and international]?

In the previous chapter, the U.S., Mexico and joint institutional capacity was assessed across scales and aspects of law, economics and politics are taken into consideration to answer the primary research question of identifying options for more sustainable transboundary management. The Conti 2014 framework enabled a comprehensive analysis of 7 factors that comprise institutional capacity. The following section discusses the three research questions through an analysis of the assessment results.

#### *Institutional Capacity Analysis*

In the Rio Grande/Bravo Basin across scale there is a mismatch in the institutional capacity. In Mexico the highest capacity to govern groundwater resources is at the federal scale while in the U.S., the state scale. In terms of joint overall capacity, the local scale has the highest capacity. These results carry significance when applied to the polycentric governance model. There are possible options for creating a treaty at the international scale, but according to- Mike Connor, former Deputy Secretary of Interior, the equitable and reasonable utilization principle, and New Mexico and Texas state laws- in the U.S. a treaty would need to be driven by the local and state water managers (personal communication, March 23, 2017). The local water managers, scientists, and general public know the specific water system the best, therefore projects and efforts are more likely to succeed if driven by local efforts from the water users themselves.

In terms of the polycentric governance model, there is not one path forward but many multi-scale options. On the global scale, there are three principles of international water law which could contribute to the creation of groundwater treaties. On the international scale, the IBWC-CILA has already been established to uphold the surface water treaties. While the IBWC-CILA could serve as a foundation for diplomatic discourse over groundwater, the most robust option is the creation of a new legally binding groundwater

treaty followed by a domestic compact to ensure implementation. On the domestic scale, the role of the federal government specific to the Rio Grande basin would be to provide some (not all) financial support and sign a legally binding binational treaty, although bearing in mind the caveat- only if federal assistance was requested by the states. Future funding efforts should be concentrated at the federal level in both the U.S. and Mexico. On the state to state scale in the U.S. the new treaties and compacts would need to account for the Rio Grande Project allocation. On a local scale, there could be another joint MOU between El Paso and Ciudad Juarez with more specific means to monitor and implement objectives. Actual enforcement of regulations or management will be left up to the agencies in each respective country. In Mexico this would be CILA, CONAGUA, and JMAS and in the U.S. it would be IBWC, NMOSE, TWDB, TCEQ, the irrigation districts EBID and EP#1 and municipal utility EPWU.

#### *Considerations for Creating a New Groundwater Treaty*

The polycentric governance scheme outlined in the Chapter 1 describes many different stakeholders interacting across the various scales. Gilberto Anaya, IBWC Chief of Environmental Division explained, “You need to have an international agreement, but the application of it would include the main users- the municipalities, agriculture, those who hold water rights who have to be involved in the process” (personal communication, March 13, 2017). In addition to the governmental agencies mentioned above, the Paseo del Norte Task Force should be involved in the decision-making process.

There are serious implications to take into consideration when forming a new international treaty. Drawing from the aspects of the eight other international agreements on groundwater around the world, the stakeholders in the Rio Grande/Bravo basin have the potential to craft the agreement to suit their specific needs. The potential arrangement would have measures range in strictness from informal handshake agreements, where each side acknowledges the over-pumping problem, to establishing conservation areas in the areas of recharge, to stricter measures where each user amount is documented annually, no pumping zones, or groundwater is allocated by percentages. Regarding with the level of strict measures, and the measures to ensure equitable allocation, the specific arrangement should be decided collectively by those in the basin.

Another consideration would be the factor of equity as a principle of international law. A person in Juarez uses half of the water each day than the average person in El Paso. Although the Juarez has double the population, a fair way to divide the water should be decided upon by the local water managers. While



consensus is touted as the next logical goal in water governance, all decision-making processes are inherently flawed (Blomquist and Schlager, 2005). When applied to the Paseo del Norte, decisions will most likely be made by those with the most power or influence in the basin. However, I maintain the inclusion of the widest range of stakeholder possible and consensus should be an overall goal in the treaty making process.

The next section offers institutional options for possible paths forward. While they are intended to be considerations, I don't intend to suggest some options are better than others. From here it is up to the stakeholders and water managers to decide the best way forward for the local people.

## **4.2 Proposed Options for Future Management**

### **NO ACTION:**

- Maintain the status quo.

The negative effects of doing nothing to increase the sustainability of the aquifer will be certain overexploitation, which will manifest in the form of hundreds of thousands of people in the region without drinking water. On the positive side, overexploitation is proposed to be a catalyst for cooperation (Conti, 2014 p. A-8). It's possible first all of the viable groundwater must be extracted in order to spur action.

### **SCIENTIFIC**

Scientists and IBWC-CILA on both sides of the border agree the aquifer levels are decreasing, and current pumping exceeds recharge. According to the TAAP 5 year Interim Report future scientific plans would ideally include “(1) integration of the hydrogeologic framework across the border, (2) development of a joint conceptual water budget for the Mesilla Basin/Conejos-Médanos aquifer system, and (3) selection, construction, and application of a mutually acceptable, fully integrated hydrologic flow model that will simulate the inflows and outflows of the groundwater and surface water of the transboundary region.” (Callegary et al., 2013 p. 28). These recommendations take into account and further elaborate on the above suggestions.

### 1. Future research on the hydrologic connection between the Rio Grande/Bravo River and Aquifers

To varying degrees, there is a known hydrologic connection between the Rio Grande River, Rio Grande Alluvium, Mesilla bolson, and Hueco bolson. Because surface water management and groundwater management are different in New Mexico, Texas and Mexico it is crucial to first determine to what extent there is a connection between the aquifer systems and surface water.

### 2. Identification of critical areas to focus artificial recharge

In order for the both aquifer storage and recovery and a binational model to be established, it is necessary for scientists to jointly research and agree on areas of recharge, the geologic boundaries of the three aquifers, and the connectivity of the aquifers to surface water.

### 3. Joint Aquifer Storage and Recovery

“Aquifer Storage and Recovery Aquifer Storage and Recovery (ASR) is when treated surface water is injected into an aquifer when it is plentiful and demand is low, and then recovered the stored water from the aquifer when demand is high or during times of drought.” (Mace, Mullican, Angle, 2001 p.72). ASR could significantly extend the life of the aquifer and it could improve water quality with strategic placement of injection wells, which would prevent saltwater intrusion (Mace, Mullican, Angle, 2001). Treating wastewater for artificially recharging aquifers is an option being evaluated in El Paso (Scanlon, Dutton, and Sophocleous, TWDB). To make ASR a reality, joint modeling would be a necessary initial step.

### 4. A joint groundwater model for the US/Mexico.

A groundwater model for this region has been already developed specifically for the U.S. side (Callegary et al., 2013). However, it is necessary to combine the U.S. and Mexican data to reach agreement on the parameters for the model.

## LEGAL/POLICY

### 1. Amendment to the 1944 Treaty by added Minute

Unlike the 1906 Convention, the 1944 Treaty has a minute mechanism which enables legally binding amendments. The 1944 Treaty technically covers the areas of the Rio Grande/Bravo basin below Fort Quitman (south of Paseo del Norte) and the Colorado Basin. However, environmental amendments have been made before, which have taken effect in the northern Rio Grande Basin. Therefore, it would be technically possible to include a minute that discusses groundwater in the Paseo del Norte region, north of Fort Quitman. In this case, since the treaty was not made to govern groundwater, highly specific provisions would need to be made to outline groundwater boundaries and jurisdictions. I would caution

that simply amending a treaty from surface to groundwater is a significant undertaking which would necessitate a careful impact assessment of groundwater withdrawals on surface water resources.

## 2. Create a new binational US/MEX agreement specifically for groundwater

A new treaty on the international scale would force the disparate legal systems of Texas and New Mexico to make room for jointly managing groundwater. I argue one of the only ways to have the states of Texas and New Mexico to agree on a groundwater arrangement would be a federal or international mandate. This binational agreement would ideally: establish a governing body, dispute resolution mechanism, a joint scientific committee, include a definition of “extraordinary drought,” both confined and unconfined aquifers, and the three applicable principles of international water law outlined below. Both water quality and quantity should be accounted for in this agreement.

### Principles of International Law

- (1) **Equitable and reasonable utilization** of the international watercourse
- (2) **Prevent significant harm**- the duty to take all appropriate measures to prevent the causing of significant harm to any other watercourse states;
- (3) **Duty to cooperate**- including the duty to exchange data and information, joint monitoring and to provide prior notification of planned new activities that could impact the other side.

The principles of international water law could provide the foundation for a new treaty. The principles were determined by reviewing the literature with specific emphasis on which would be most applicable to the groundwater situation in Paseo del Norte. The most relevant literature reviewed specifically for this purpose included Bellagio Draft Treaty 1989, Maria Milanese. 2013, Conti and Gupta 2016, and Eckstein 2007; Eckstein 2011.

## 3. Regional agreement between the cities

There could be a regional agreement modeled after the Franco/Swiss Genevese Aquifer Convention. There has already been a foundation established by the joint MOU between El Paso and Ciudad Juarez. The potential agreement would ideally have more specific guidelines for pumping arrangements, aquifer recharge, and data sharing.

A policy restricting the depth and capacity of the agricultural pumps is unprecedented and would be difficult to enforce. Likewise, a policy taxing higher value crops would also be politically unpopular. “Water managers in Texas agree on the need for transferring agricultural water to municipal use. This is not the case in New Mexico, and controversial in Mexico. Whether this transfer will use market mechanisms, such as water markets, or regulation, and whether it will happen peacefully or because of political and social conflict, is uncertain.” (Schmandt, 2002 p. 149). While this paper does not recommend a specific state or city wide policy, I encourage the development of a policy which would either further heighten awareness of groundwater issues, or restrict groundwater use.

## ECONOMIC

### 1. Economic water banking

Maria Milanes-Murcia proved through her dissertation work that the economic benefits of a water banking system would potentially increase the economy by \$106 million per year in the United States and \$69 million per year in Mexico (Milanes-Murcia, 2013 p. 9-3). The goal of the system would be to effectively trade, sell and buy water rights, creating a market that would enable distribution of water to agriculture, environment and municipal uses. The system would develop a comprehensive “water use right” to account for both groundwater and surface water where the distinction would not be made between the two, effectively conjunctively managing all of the usable water in the Lower Rio Grande Basin (Milanes-Murcia, 2013). To gain authority, this system would need to be actualized through an added Minute to the 1944 Treaty in addition to the creation of a new water bank institution for implementation. Although this scheme would take years to actualize because there must be an accurate record of the existing water rights, it would be more politically acceptable than privatization, which has received significant pushback along border on the Mexican side – see Mexicali protests (Mexico News Daily, 2017), and Baja California protests (BN Americas 2017b) and Mexican legislative denial of a water privatization law in 2015. Economic water banking would also need to be approved by the IBWC-CILA, and likely both federal governments.

### 2. Future Joint Development

- a. Desalination plant in Ciudad Juarez, or joint water treatment plant
- b. Joint industrial development with groundwater pumping restrictions

A joint economic investment in physical infrastructure, such as a desalination plant or wastewater treatment plant could benefit both the U.S. and Mexico. It is important to take into account the different priorities for water uses in Mexico and the U.S. While in Ciudad Juarez, industry uses a large majority of the water, and on the U.S. side, agriculture accounts for up to 80% of the water use. A common water use interest lies in the responsibility of both cities municipalities to provide a steady domestic water supply. To keep up with the growing population water demands it is likely this infrastructure will be needed regardless. The unified development could strengthen partnerships and benefit both sides. The institutions already exist to create such a development (NAFTA and BECC).

## INSTITUTIONAL

First, if an agreement is made, it would be critical for these institutions be established for implementation purposes. Second, these institutions need to have the built in ability to be flexible and adapt as the different supply and demand needs change over time. “Based on the experience of the SCERP project team, successful efforts at cross-border data integration and fusion on the U.S.-Mexico border *will require a multi-institutional effort over a series of years and a commitment of financial resources* orders of magnitude greater than have been previously committed by interested agencies” (Brown et al, 2005)

### 1) Public Education of Groundwater/Water Use awareness

If the local people do not perceive groundwater exploitation as a problem, there won't be anything agreed on this. Education efforts could manifest through school initiatives, serious water gaming in schools, public outreach, efforts through social media, or factual groundwater website development. Websites could be created by the city water utilities, state agencies, or non-profit agencies. There would be a high impact from a website explaining the science behind groundwater movement, and groundwater levels. Considering the rate of water consumption of the average person in El Paso is double that of Ciudad Juarez, efforts should begin but not be limited to El Paso. Figure 15 depicts how the local water board has installed a groundwater gauge in Drenthe, Netherlands, to enable local citizens to monitor changes in groundwater levels. This is a feasible step that could be implemented in public parks in Las Cruces, El Paso, and Ciudad Juarez. The monitoring well would be clearly marked like the one in the sign, with red, yellow and green markers for water. A concise explanation with simple terminology should be provided for the well.



Figure 15: Example groundwater monitoring well with groundwater levels made publically accessible. (Van der Zaag, 2016).

## 2) Create a new management branch in IBWC

This branch would be solely dedicated to authorizing groundwater related data sharing and transactions. They would work in conjunction with the Paseo del Norte regional council, whose goal is to come up with realistic, sustainable groundwater plan for the basin. This would allow for bottom up stakeholder input regarding the management of groundwater. The agency would be funded by IBWC-CILA.

## 3) Create a new joint management branch between the city water utility monopolies (JMAS and EPWU)

This management branch would function to govern a potential agreement created by the cities. It could be modeled after the Genevese Aquifer agreement. Specific places to start would be to identify common concerns and priority of concerns, create joint planning strategies, assess current water supply and demand, share data and technology. This agency would ideally be jointly funded by the respective cities.

## 4. Establish a Groundwater Conservation District in El Paso

A Groundwater Conservation District would change the management structure of water in El Paso. There are three ways to establish a groundwater conservation district. First, if the local citizens want a conservation district established, they approach the legislature with a signed petition and proposal.

Second, the legislature could impose a groundwater conservation district if they think conservation measures need to be taken because groundwater will be running out in the near future. Third, if the area of concern lies within the boundaries of a state-declared priority management area, and measures are not being taken to appropriately conserve groundwater. This last option is unlikely to happen because there are less than 5 priority management areas, none of which are in El Paso County (Anonymous interviewee, Texas Commission Environmental Quality, personal communication, April 2017). Of the three options, GCD's are most commonly instigated by local citizens and water managers that decide for various reasons there should be controls to enhance the longevity of the groundwater (Anonymous interviewee, Texas Water Development Board, April 2017). If locals decided this would be a necessary action, the local water managers would be responsible for establishing an individual plan, specific to the needs of the water users of the Mesilla and Hueco bolsons. The Texas Water Development Board would oversee the management, and need to approve the plan.

The reasons why and why not the GCD has not yet been established is largely political (Rosario Sanchez, Researcher, Texas A&M, personal communication March 22, 2017). A potential factor is El Paso is an area highly controlled by EP#1 irrigation district and it is an epicenter for economic development. Limiting groundwater use would limit the potential for economic growth. Some argue the EPWU has one of the most highly sophisticated water distribution systems, which includes the largest inland desalination plant in the country. Perhaps even the threat of a groundwater conservation district by local citizens would be enough to spur the local water managers to create a transboundary groundwater arrangement on their own.

### 5. Task Force to replace TAAP

The general goal would be a platform in which continue active discussion between Mexican/American scientists. The 10-year effort of the TAAP project successfully established individual partnerships. In some form or another this communication should continue. There would need to be consistent funding on both sides to make this option operational. Since the individual personal relationships have largely been established by the TAAP project, in theory it would not take as long to begin cooperative discussions. IBWC Commissioner Edward Drusina, "Understanding...transboundary aquifers is the first step in planning for a clean and adequate water source for future generations, I am confident that this new binational partnership that developed under this TAAP project, led by cooperative, responsible experts with our support, will continue to study our border groundwater" (USGS, 2016).

### 4.3 Discussion of Options

*How does expected outcomes compare with actual outcomes?*

The main expected outcome from this research was, amending the existing 1944 surface water treaty to include groundwater would be one of the most feasible solutions to introduce groundwater management institutions in the basin. Contrary to my expectation, through my interviews I found amending the 1944 treaty is a feasible option, but not popular among the stakeholders in the basin. The primary reason stakeholders provides was, the 1944 treaty was created for the purpose of managing surface water, not groundwater. Amending the treaty to include groundwater would require many details and a new institution to be created to implement the measures. Areas of recharge, discharge, groundwater permeability, hydrologic connectivity need to be accounted for. Instead, interviewees were in favor of creating a completely new arrangement which included provisions for a comprehensive groundwater strategy.

*What is the best option?*

Any of these options would be considered a step forward from the current state of groundwater management.

*When will we exhaust the groundwater resources?*

Since the Rio Grande Alluvium is a shallow unconfined aquifer, the recharge is heavily linked to the river water levels and the discharge is linked to groundwater pumping. Thus, the longevity of Rio Grande alluvium is tied to the flows of the Rio Grande/Bravo river.

“The Hueco Bolson aquifer is pumped at a much greater rate than the aquifer is recharged (Sheng et al., 2001). Groundwater withdrawals from the aquifer in Texas amounted to about *nine* times greater than the amount of recharge in El Paso County” (Mace, Mullican, Angle, 2001 p219). The Hueco Bolson is estimated to be exhausted between 2020-2050 (Sanchez et al., 2016).

Water managers are now turning to the Mesilla Bolson to meet municipal groundwater demands. “About 2% of the mean annual precipitation of 8 to 9 inches contributes to recharge outside the inner river valley. Present and projected basin wide groundwater use greatly exceeds this amount.” (Mace, Mullican, Angle, 2001 p. 94). There is not yet an estimated date when the Mesilla aquifer could be exhausted. Mike



Hightower, a Sandia National Laboratories civil engineer said, “These current wells that may not be projected to become brackish for 30 years down the road could become brackish in half the time” (Vilagran, 2016). If there are no controls put in place, the Mesilla/Conejos Medanos will likely follow a similar fate as the Hueco Bolson.

*Which option is likely to happen first?*

Many of the options are contingent upon another option happening first. Though it is impossible to predict in what manner or timeline these possibilities could come into fruition, a few definitive facts can be determined.

- A more substantial scientific understanding of the shared aquifers is needed before decisions makers can create an effective management plan.
- A joint scientific effort is necessary for trust building, relationship building, and credibility. Domestic science serves a significant purpose build a basic understanding of water quality, quantity and timing, but will not suffice when the resource is transboundary.
- A binational scientific effort requires simultaneous funding from both sides. Funding from both sides of the border is certainly not synchronized, and driven almost entirely by political will.
- On the international scale, the IBWC is *formally unable* to legally manage groundwater without a treaty or added minute amending the treaty. Therefore, any lasting transboundary cooperative efforts which need to go through the IWBC will require legal backing through a new treaty or amendment to the 1944 treaty.
- Under the current political climate, any binational agreement on the federal scale would almost certainly be wrapped into a bigger issue, akin to national security. The Chazimal Dispute in the 1960’s was an example of when a water agreement was used a bargaining chip in a much bigger political dynamic (the Cold War).
- The political reality on the U.S. side determines the motivation for a treaty would need to come from the state scale. Namely, the federal government will not likely sign a treaty unless the need is expressed by the states or it is wrapped up in a larger political agreement (Mike Connor, former Deputy Secretary of Interior, personal communication, March 23, 2017). Individual voices from any one of these stakeholders will not be enough. However, if water managers agree a unified voice could be powerful enough to sway state action, which in turn could sway federal action.

### *Funding?*

The basis for new institutions, new joint research and new economic development projects all require financial support. Annual funding is tied directly to political will. The political will to manage groundwater is significantly higher among the local managers than on the federal level. However, it is the federal government that is able to allocate funding. If local managers can assemble to collectively request federal funding, the chances of allocation are higher but certainly not guaranteed.

### *Conjunctive Management?*

It is important to note a few distinctions between managing surface water and groundwater. Gilberto Anaya says the groundwater agreement could follow the same basic structure of the Compact (personal communication, March 13, 2017). Under the Compact, the surface water availability shifts from year to year and it is allocated according to percentages. Groundwater cannot be managed the same because it does not range in quantity from year to year, instead it is conceptualized more as a unit of storage.

The (theoretical) principles of IWRM call for surface and groundwater to be conjunctively managed. In reality, conjunctive management in the Paseo del Norte region would be nearly impossible given the complexity and development of the current disparate legal regimes for surface and groundwater in New Mexico, Texas and Chihuahua. “It is clearly an interrelated system that necessitates conjunctive management that administratively is anything but conjunctive.” (Erek Fuchs, Groundwater Resources Manager EBID, personal communication, January 23, 2017). From the proposed options, the economic water banking scheme would be the only possibility to conjunctively manage the water.

### *What are future factors that could affect the options?*

There are many possibilities which could influence the future of groundwater management. The following list are a few of the immediate possibilities, but not a complete list.

- Politics in the Trump era
- Adjudication of the Lower Rio Grande
- Extreme drought
- The outcome of the Supreme court case *Texas v New Mexico*

There are serious management implications regarding the extent of the hydrologic connection between the Rio Grande River, Rio Grande Alluvium, and the Mesilla and Hueco bolsons. More scientific research is needed to determine the extent of the connection. The surface water in the Rio Grande Basin has been over-allocated, and is currently meticulously managed by the irrigation districts within the Rio Grande Project. The outcome of the ongoing Supreme Court Case Texas v. New Mexico could change how this hydrologic connection is interpreted under federal law. The case is extremely complicated and involves a ruling on the Compact delivery location. Nevertheless, if the Supreme Court Case rules in favor of Texas, it would recognize the connection between the river and the groundwater pumping in the Rio Grande Alluvium thus holding New Mexico accountable for either billions of dollars in damages or a serious wet water debt. For the future management of the basin, groundwater pumping in the Lower Rio Grande Basin of New Mexico would be even more highly regulated than it is now. One of the small ironies with this outcome would be Texas, which does not regulate groundwater in Paseo del Norte, whose Canutillo well field is located on the New Mexico border, would not owe reparation for any damages caused by their pumping the transboundary groundwater.

#### 4.4 Limitations

- The aim of this assessment was to capture the major water management institutions interacting across a specific region between the U.S. and Mexico. It is intended to be an overview and not an exhaustive list of the players and organizations interacting.
- Although the assessment was of both the United States and Mexico, in person interviews only occurred on the U.S. side of the border. Since it is imperative to gain the Mexican perspective, these interviews were conducted over the phone. Since this research is part of another initiative, interviews with Mexican stakeholders collected on the Mexican side of the border were also used to augment this research and vice versa.
- This analysis does not explore what *could happen* give the present political climate in both the United States and Mexico. The current president of the United States has vowed to repeal NAFTA, among other things. Hence the questions of “if” were left completely out of the picture due to the current political uncertainty and counter productivity of considering the countless possibilities.

- This assessment does not characterize the social capital, relationship and cultural values between the two countries. It is a difficult task to measure or otherwise identify social drivers regardless of the framework. However, I recognize the impact of social capital within the Paseo del Norte region is an important piece of the overall puzzle.
- This assessment takes into account but does not focus on the transboundary relationship that exists on a state to state scale between New Mexico and Texas. Due to the ongoing lawsuit between the two states, water managers are not compelled to discuss state to state dynamics. There is also conflict between Mexico states over 1944 Treaty obligations. Future research could include a deeper examination of the state/state relationship on both sides of the border.
- Although it is occasionally implied, joint cooperation is not the end goal; it is the mechanism in which to achieve the goal. The goal for this research is increased sustainable use of groundwater.

#### *Future Research*

Because this study focused on identifying feasible options to increase sustainable management of groundwater, there are many opportunities for future research. First, expansion on the feasibility of any of the options I mentioned would be useful. Second, examining the virtual water trade across the U.S./Mexico border would be extremely interesting given the difference in water uses between the two countries (agriculture and industry respectively). Third, the exact influence of the cartels in Ciudad Juarez on the water sector concessions is difficult to measure from behind a computer. Although I'm not sure it is feasible, it would be interesting to know the deeper power dynamics of the cartels and levels of governmental corruption are affecting water use.

## CHAPTER V. CONCLUSION AND RECOMMENDATIONS

### Research Questions:

1. What are options to sustainably manage transboundary groundwater?
2. Institutions are currently best equipped to jointly manage groundwater across which scales?
3. How can legal, economic and scientific options contribute to more sustainable management of transboundary groundwater across scales [local, state, national, and international]?

### *Problem Synthesis*

The primary problem facing the Paseo del Norte region is intensive aquifer depletion- where groundwater pumping rates greatly exceed recharge rates. The groundwater of the Hueco and Mesilla Bolson is nonrenewable, between 10,000-15,000 thousand years old. While we have relied on groundwater for thousands of years, intensive groundwater mining did not begin in the southern United States until the 1950's and 1970's in Mexico. It seems within 100 years we will have managed to exhaust one of the largest groundwater reserves in the Chihuahuan desert. Scientists predict total freshwater aquifer depletion between 2020-2050 in the Hueco bolson and no measures are being implemented to prevent future overdraft of the Mesilla bolson. Multi-faceted causality contributes to this problem to varying degrees. Known drivers of overdraft have been identified as: rapid population growth and a more diverse array of water users; drought triggering surface water scarcity and prompting water users to pump more groundwater; lack of political will and poor regulation of groundwater pumping in Texas and Mexico; institutional incompatibility between water management agencies the U.S. (state level) and Mexico (federal level); a growing database yet still partial scientific knowledge of complete aquifer systems; economic development driving pumping within the agricultural sector in the U.S. and industrial sector in Mexico. While the following conclusions are not intended to be the ultimate solution to this problem, they recommend possible ways to improve the existing situation.

### **5.1 Recommendations**

This research assessed the individual and joint capacity the U.S. and Mexico at the federal, state, and local scale. According to Willems et al., 2003 “the level of existing capacities in a country is likely to define the kind of next step that the country can take.” Assessing institutional capacity, provides one

conceptual model in which to perceive the existing situation. Understanding the actors, networks and agencies that comprise this setting enables identification of pertinent future options for more sustainable management. These results could be useful for water managers, developers and/or any decision makers considering the future challenges of meeting of water supply and demands. Acknowledging the primary problem of aquifer exploitation, I make the following five recommendations:

1. First steps to increase sustainability would include making the problem of aquifer overexploitation of nonrenewable groundwater known to all the involved stakeholders (private investors, citizens, non-profit agencies, environmental groups etc.). Collectively acknowledging we are depleting a nonrenewable resource is a crucial first step. Specifically, publically displayed groundwater gauges like the one in Figure 15 could be installed in parks throughout the cities of Ciudad Juarez and El Paso.
2. Additional first steps forward should include an emphasis on binational scientific research. My research found scientific cooperation is the only factor that transcends across all of the institutional scales. The ability for scientists on multiple scales to communicate across the border carries compelling weight for three reasons. First, knowledge of aquifer recharge and discharge areas would be a necessary first step to guide effective water management planning. Second, joint data gathering for physical properties of the aquifer is essential to provide validation needed for (IBWC-CILA) to support and fund future projects. Third, achieving agreement on both sides can avoiding future disagreement, build trust and increase credibility for all scientists. Consequently, I recommend immediate funding, resources, and attention should be directed towards continuing scientific discussions on developing a binational groundwater model to serve as the foundation for any potential groundwater sharing arrangement.
3. The scalar difference in institutional capacity between the U.S. and Mexico should be taken into account. Whether or not these differences are interpreted as boundaries or opportunities depends on how they are accounted for in financial planning and cooperative discourse. Recognizing the water management agencies within the states of New Mexico and Texas and the federal government of Mexico (CONAGUA) need to be included in *all* serious binational discussions should help to avoid future misunderstandings, increase communication and build working relationships. While the institutional situation is complex, it is not impossible to navigate.

Therefore, I recommend future efforts recognize and embrace the complexity of the water management situation and include the proper governing agencies in all binational discussions.

4. Political will at the local level could be capitalized on by uniting local water managers across borders with the shared problem of aquifer exploitation. The local scientists and water managers undeniably know the resource and the associated issues the best. Exhausted groundwater resources leading to shortage of potable water will directly affect the local populations, therefore they should be the most compelled to act.
5. With certainty, proactive planning for the long term will be cheaper than reactive measures like environmental remediation, inter-basin transfers, or attempting to clean highly contaminated groundwater. In many instances once fossil groundwater is removed, the land compacts and renders further storage improbable. While I understand there are many ways forward, the final recommendation is for water managers, stakeholders, and citizens to take action, even small steps towards using groundwater more sustainably.

## 5.2 Implications for the Paseo del Norte Region

*“19th century water law, 20th century infrastructure, and 21st century population growth and climate change are on a collision course.”*

(Dettinger, Udall, & Georgakakos, 2015 p. 2093)

The statement above gracefully outlines a paradoxical issue of timing with the confluence of many issues. The Paseo del Norte region found within the Rio Grande basin “is the best example of how climate-change induced flow declines might sink a major system into permanent drought” (Dettinger, et al., 2015 p. 2069). Quite simply, “If something is not done soon on the policy level, the aquifer is simply going to run out before our scientific understanding can catch up with the politics” (Maria Milanes-Murcia, personal communication March 10, 2017). Realistically a groundwater model will take years to develop, then years to test in the field before it can be pronounced accurate. Concurrently, water managers can’t

be expected to manage what they don't know. The sense of urgency that accompanies the depletion of these aquifers is understood by strikingly few among the population of these arid cities, and it is profoundly absent from the political discussions across all scales.

This enigma of timing between scientific knowledge and policy governing water resources fundamentally changes the conversations surrounding the management of groundwater. The discourse surrounding nonrenewable groundwater should be innately different, with the above paradox provoking questions of how much scientific knowledge is needed to make policies on groundwater? What is sustainable, for whom, and for how long? How should equity be interpreted in the context of groundwater along the U.S./Mexico border? Before addressing these questions, I call for a reframing of the way Americans in general view water use and water waste.

When looking at options for the future, we need not be bound to only what we have done in the past. Reframing how we approach water management decisions includes questioning how to put limits on economic growth. Quite simply, the availability of water is a limiting factor for economic growth. Over the past century the Paseo del Norte region has been dominated by economic development and groundwater has been used to buffer a diverse onslaught of water demands. Hard questions of how to plan for future population growth and cap groundwater pumping will likely be seen as attempts to limit economic growth. Yet continuing down the same path of enabling economic growth to dictate decisions will only continue to make those in power more powerful. For example, reducing water for agricultural use will most likely happen when groundwater levels drop below economically extractable range. However, up until this point, only the wealthy farmers and companies will be able to afford drilling deeper and deeper wells. With certainty, as the scarcity of the groundwater increases, so will the value.

There are no longer easy, inexpensive options to increase the availability of surface water in the Paseo del Norte region. When surface water is not available, citizens, farmers, and industry turn to groundwater as to buffer the water demand. Though groundwater has been used to supplement surface water, we are soon approaching a time where some aquifers will no longer be available. While this is true, the exact extent of the damage is impossible to predict. "Climate changes will inevitably alter the form, intensity, and timing of water demand, precipitation, and runoff, meaning past climate conditions are no longer an adequate predictor of the future." (Gleick, 2014 p. 2). Similar to Gleick's warning our future climate reaching a realm beyond our ability to predict, I believe we are entering into a new era in which many of



our groundwater resources are in danger of being overexploited irreversibly. The types of choices we will need to make are going to be unprecedented. Water managers and politicians need to actively start making steps towards planning for this future by prioritizing drinking water as requirement for human life, and basic human right.

The associated implications that accompany the complete exhaustion of a natural resource will drive us to create new solutions and evolve differently. Frankly, I believe as Americans, we are the biggest users of water per person around the world. Although the Juarez has double the population, one person in Juarez uses half the amount of water as a person in El Paso. It can be inferred there is a large quantity of water being wasted. Whether or not we choose to recognize it ahead of time or too late will change the landscapes and population centers in the dry regions of the world. We should begin reconciling how our water use (and waste) water affects our neighbors, especially our water scarce southern neighbor. The interconnected nature of hydrologic cycle coupled with our virtual water footprint points to our levels of consumption (and waste) affecting not only our neighbors, but everyone around the world.

Precisely how *sustainable* is defined by the water users in the basin is neither correct nor incorrect. It's more important to start having bilateral conversations on how to define sustainability and how to allocate water equitably. Given the potential institutional capacity govern groundwater, knowledge of the problem, and scientific capacity to address it, we can no longer afford to ignore this "mysterious" resource or pump groundwater unilaterally.

Milman and Ray (2011) found "prioritization of water use and sovereignty concerns drive and legitimize unilateral decisions" (p. 641). However, Eckstein (2013) warns of the dangers of unilateral development. "Essentially, both nations [U.S. and Mexico] have permitted landowners, companies, public entities, and others to construct wells all along the border and to withdraw groundwater, within their respective territories, in response to the increasing needs of their individual citizens and economies" (Eckstein, 2013 p.105). The governance of a common pool resource such as a transboundary aquifer will fall prey to the theory of tragedy of the commons unless both sides are willing to communicate and cooperate to plan for the longevity of the groundwater. The result could be the mutual benefit of all parties, or just as easily, the complete exhaustion of a primary drinking water source in a desert.

While political boundaries label ownership of the water, the bottom line is, it is all the same water.

Disparate legal systems, water management institutions and economic development are all boundaries to transboundary water sharing, but they can also be opportunities for improvement. Despite many of the converging problems facing groundwater stress worldwide, I remain optimistic water has a unique power to unite a broad range of people, culture, and interests. There is not simply one solution to a problem this complicated but instead combinations of future options that must be chosen by the water users. Franklin Roosevelt said, "There are many ways of going forward and only one way of standing still." Perhaps we should try standing still long enough to ponder the long term consequence of our actions.

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## APPENDIX A.

**List of Acronyms**

(BECC) Border Environment Cooperation Commission  
 (BLM) Bureau of Land Management,  
 (BoR) Bureau of Reclamation  
 (CILA) Comision Internacional de Limites y Aguas  
 (CONAGUA) National Water Commission,  
 (CNA) Comisión Nacional del Agua  
 (EBID) Elephant Butte Irrigation District  
 (EPCWID/EP#1)- El Paso County Water Improvement District  
 (EPA) Environmental Protection Agency  
 (ESA) Endangered Species Act  
 (EPWU) El Paso Water Utility  
 (GCD) Groundwater Conservation District  
 (GIS) Geographic Information System  
 (GMA) Groundwater Management Area  
 (IBWC)- International Boundary and Water Commission  
 (ICJ) International Court of Justice  
 (IGRAC) International Groundwater Resources Assessment Centre  
 (ILA) International Law Association  
 (ILC) International Law Commission  
 (INEGI) National Institute of Statistics and Geography  
 (IWRM) Integrated Water Resources Management  
 (JCAS) Juntas Centrales de Agua y Saneamiento  
 (JMAS) Junta Municipal de Agua y Saneamiento de Ciudad Juárez  
 (NADB) North American Development Bank  
 (NAFTA) North American Free Trade Agreement  
 (NMSU)- New Mexico State University  
 (NMWRRI) New Mexico Water Resources Research Institute  
 (OSE)- New Mexico Office of the State Engineer  
 (SDGs) Sustainable Development Goals  
 (SEMERNAT) Secretaria de Medio Ambiente y Recursos Naturales  
 (TAAA) Transboundary Aquifer Assessment Act  
 (TAAP) Transboundary Aquifer Assessment Project  
 (TCEQ) Texas Commission on Environmental Quality  
 (TWDB) Texas Water Development Board  
 (UN) United Nations  
 (UNECE) United Nations Economic Commission for Europe  
 (USFS) United States Forest Service  
 (USGS) United States Geological Survey

**\*United States Affiliation**

**\*\*Mexican Affiliation**

## APPENDIX B.

### Definitions

**Compact** - An agreement between two or more states to resolve competing demands for water resources

**Interstate:** Interactions between two or more states. (Human Security Report, 2010). The interstate relationship here discussed is between the U.S. and Mexico and well as Texas and New Mexico.

**Intrastate:** Interactions that originate and end inside the state's territorial boundaries. (Human Security Report, 2010).

**Nonrenewable Groundwater-** Not replenishable, or unrecoverable, within a period less than a human lifespan (Ponce, 2007)

**Transboundary Aquifer-** Ground water resources that traverse an international political boundary between two or more sovereign states or that are hydraulically connected to surface water that traverse a boundary" (Y. Eckstein and G. Eckstein, 2005).

**Transboundary Basins** Are surface water or groundwater basins (aquifers) which cross or are located on boundaries between two or more States.

**Renewable Groundwater-** Replenishable or recoverable within a period less than a human lifespan (Ponce, 2007)

**Sustainable Development-** "Aims to meet the needs of present generations without compromising on the ability of future generations to meet their own needs." (United Nations Documents, p. 43)

**Governance-** "The overarching framework of groundwater use laws, regulations, and customs, as well as the processes of engaging the public sector, the private sector, and civil society." (Megdal et al., 2017)

**Water Governance-** The range of political, social, economic and administrative systems that are in place to regulate the development and management of water resources and the provisions of water services at different levels of society. (Pahl-Wostl et al., 2008).

### Technical definitions

**Aquifer-** "Permeable layers of subsurface rock that are saturated with groundwater." (Fitts, 2002).

**"Basin" and "bolson"-** Used as alternative designations for large intermontane-basin landforms and the associated sedimentary fill.

**Confined aquifers-** Are found between semi-permeable or impermeable layers of rock (Margat and Van

der gun, 2013). When a well is drilled into a confined aquifer, the water that is under pressure in it will rise in the well casing and may reach the surface (Texas Water Law, 2014)

**Closed basin-** Is a bounded topographic depression that has no external drainage. Water within such basins can only exit the basin through evaporation or human use (Eckstein, 2011)

**Cone of Depression-** As the water table declines, there is a radial flow as surrounding groundwater moves laterally toward the region of lower pressure. (Hamlyn et al., 2002) This is commonly caused by wells.

**Groundwater-** The water saturating the pores of the earth's subsurface (Fitts, 2002)

**Hydraulic Conductivity -** The [mean] velocity of flow through soil or rock formation (Ponce, 2007)

**Hydrologic Cycle-** The continuous movement of water on, above, and below the surface of the Earth (USGS, 2016a)

**Recharge-** Water that moves from the land surface or unsaturated zone into the subsurface saturated zone (Nimmo et al., 2005).

**Unconfined Aquifer-** When the shallow groundwater table is in direct contact with the atmosphere through soil or rock pores (Margat and Van der gun, 2013). The water level in wells drilled into an unconfined aquifer will be at the same elevation as the water table. (Texas Water Law, 2014).

#### Conversion Factors

1 cubic-foot of water = 7.48 gallons, or 28.31 liters

1 gallon of water = 0.13368 cubic feet, or 3.78532 liters

1 cubic-foot/sec (cfs) = 1.9835 acre-feet/day, or 724.46 acre-feet/year

1 cubic meter = 35.3 cubic feet

1 acre-foot = 325,851 gallons, 1,233,500 liters, 1,233.5 cubic meters

## APPENDIX C.

## IRB Exemption Form



**Human Research Protection Program**  
*Institutional Review Board*  
 Office of Research Integrity  
 8308 Kerr Administration Building, Corvallis, Oregon 97331-2140  
 (541) 737-8008  
[IRB@oregonstate.edu](mailto:IRB@oregonstate.edu) | <http://research.oregonstate.edu/irb>

**DETERMINATION**

Date of Notification	11/22/2016		
Study ID	4803		
Study Title	The Role of Transboundary Aquifers in Bilateral Agreements		
Person Submitting Form	Christina Welch		
Principal Investigator	Aaron Wolf		
Study Team Members	Christina Welch		
Funding Source	None	Proposal #	N/A
PI on Grant or Contract	N/A	Cayuse #	N/A

**DETERMINATION: RESEARCH, BUT NO HUMAN SUBJECTS**

The has been determined that your project, as submitted, does meet the definition of research but **does not** involve human subjects under the regulations set forth by the Department of Health and Human Services 45 CFR 46.

Additional review is not required for this study.

Please do not include HRPP contact information on any of your study materials.

**Note that amendments to this project may impact this determination.**

The federal definitions and guidance used to make this determination may be found at the following links: [Human Subject](#)

## APPENDIX D.

**List of Interviewees I.**

#	Date	Category	Name	Affiliated Organization	Location
1	12/28/16	Lawyer	Greg Hobbs	Colorado Supreme Court	Denver, CO
2	1/20/17	NM State	Tom Blaine	Rio Compact Commissioner & NM State Engineer	Santa Fe, NM
3	1/20/17	Lawyer	Adrian Oglesby	Utton Transboundary Water Center	Albuquerque, NM
4	1/23/17	Consultant	John Shomaker	Shomaker Associates	Albuquerque, NM
5	1/23/17	Irrigation District	Gary Esslinger	Elephant Butte Irrigation District (EBID)	Las Cruces, NM
6	1/23/17	Irrigation District	Erek Fuchs	Elephant Butte Irrigation District (EBID)	Las Cruces, NM
7	1/23/17	Irrigation District	Phillip King	Elephant Butte Irrigation District (EBID)	Las Cruces, NM
8	1/23/17	NM State	John Fleck	University of New Mexico	Albuquerque, NM
9	1/24/17	Lawyer	Pat Schaefer	Hunt Institute	El Paso, TX
10	1/25/17	Environmental NGO	Kevin Bixby	Southwest Environmental Center	Las Cruces, NM
11	1/25/17	NM State	Maria Murcia	New Mexico State University	Las Cruces, NM
12	1/26/17	Irrigation District	Jesus Reyes	El Paso County Water Improvement District (EP#1)	Clint, TX
13	1/26/17	Farmer	Anonymous	Farmer	New Mexico
14	1/26/17	Irrigation District	Mike Hamman	Middle Rio Grande Conservation District	Albuquerque, NM

**List of Interviewees II.**

#	Date	Category	Name	Affiliated Organization	Location
15	2/28/17	Lawyer	Gabriel Eckstein	Texas A&M	College Station, TX
16	3/2/17	U.S. Scientist	Chris Scott	University of Arizona	Tuscon, AZ
17	3/10/17	Consultant	Kirstin Conti	IGRAC	Delft, NL
18	3/13/17	IBWC	Gilberto Anaya	IBWC	El Paso, TX
19	3/14/17	U.S. Scientist	Delbert Humberson	USGS	El Paso, TX
20	3/21/17	U.S. Scientist	Sharon Megdal	University of Arizona	Tuscon, AZ
21	3/22/17	Mexican Scientist	Rosario Sanchez	Texas A&M	College Station, TX
22	3/23/17	Federal Government	Mike Connor	U.S. Department of Interior	Washington DC, USA
23	3/25/17	Mexican Scientist	Jorge Salas-Plata Mendoza	Universidad Autonoma de Ciudad Juarez	Ciudad Juarez, MX
24	3/31/17	U.S. Scientist	Anonymous	Texas Agrilife Extention Center	El Paso, TX
25	4/3/17	Mexican Scientist	José Luis Castro Ruíz	El Colegio de la Frontera Norte	Monterrey, MX
26	4/11/17	Mexican Scientist	Alfredo Granados Olivas	Universidad Autonoma de Ciudad Juarez	Ciudad Juarez, MX
27	4/19/17	TX State	Anonymous	Texas Water Development Board	Austin, TX
28	4/19/17	TX State	Anonymous	Texas Commision Environmental Quality	Austin, TX